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Preliminary Design of a

FLOX DISCONNECT FOR A FLOX-ATLAS VEHICLE

FINAL REPORT

GD/C-BHV65-004
13 Sept. , 1965

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NASA

PRELIMINARY DESIGN OF A FLOX DISCONNECT FOR A FLOX-ATLAS VEHICLE

by

L. E. Siden, A. P. Traskell, R. H. Anderson

Prepared for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

CONTRACT NAS 3-3245

GENERAL DYNAMICS
Convair Division

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Washington, D.C. 20546

FOREWORD

This report, containing the results of a preliminary design program sponsored by the National Aeronautics and Space Administration, was prepared under General Dynamics/Convair TCP 8436 in compliance with Contract Number NAS3-3245, Task Order Number 3.

ABSTRACT

19692

This report presents the results of a study program to establish a preliminary design of a multiple purpose disconnect for use in a FLOX-Atlas oxidizer system. Design requirements are defined, current technology is reviewed, and a selected valve design is presented and installed in three locations.

Author

INTRODUCTION

The use of 30% FLOX (30 percent fluorine and 70 percent oxygen) as the oxidizer for the Atlas Space Launch Vehicle has been proposed as a method of increasing the Atlas vehicle payload capability. Rocketdyne engine tests, coupled with analytic studies, have indicated that significant increases in specific impulse and density impulse can be expected using the new oxidizer and the normal Atlas hydrocarbon fuel, RP-1. It is anticpated that only minor changes would have to be made to existing Atlas oxidizer components to accept 30% FLOX.

Two test programs were funded by the National Aeronautics and Space Administration, Lewis Research Center, to General Dynamics/Convair to feasibility test major Atlas components with 30% and 50% FLOX. These programs demonstrated that modified Atlas components are compatible with 30% and 50% FLOX.

The FLOX disconnect documented in this report is a new valve designed to serve as a fill and drain, boil-off and staging disconnect. Designing the disconnect for three different locations will impose the maximum requirements of each location upon the disconnect.

SUMMARY

A survey was conducted to establish current technology on recent disconnect developments and principles of operation. Principles presently in use were documented into the main categories of flow area, disconnect area, actuator and flexible ducting.

A performance specification was written which contains the design and performance requirements for the disconnect as used for fill and drain, interstage, and boil-off disconnects. The maximum requirements of the three different locations were imposed upon the disconnect.

The configuration was divided into several sections such as the flow area, disconnect device, disconnect seal, actuator, etc. Several designs were then generated for each section and evaluated. The design candidates from each of these areas were then used to create three basic valve configurations. These three configurations were then evaluated and one selection made. Final design activities then proceeded on the basis of this single selection.

CONTENTS

1.0 Current Technology

The following manufacturers were visited to acquire information on current technology used in valves and disconnects:

Fairchild Hiller, Stratos Division
Manhattan Beach, California

AiResearch Manufacturing Company
Phoenix, Arizona

Snap-Tite, Inc.
Union City, Pennsylvania

Aeronca Aerospace Division
Baltimore, Maryland

Thiokol Corporation, Reaction Motors Division
Denville, New Jersey

A literature survey revealed that Advanced Technology Laboratories of General Electric Company and Rocketdyne Division of North American Aviation have both accomplished thorough searches of available literature on valves and related subjects and have published reports on findings, along with the results of their own research on seals and sealing carried out under government contracts.

The research on current technology by these companies revealed that there was no generally accepted technology developed for valves and sealing. The large number of parameters involved are lacking in definition and categorization. Each manufacturer has developed a technology based on his own experience or peculiar circumstances evolving from the nature of the product he is designing or producing. The illustrations shown in Figures 1 through 8 give a representative cross-section of missile hardware currently in use and which generally represents the status of current technology.

1.1 Flow Area and Closure

The flow area or flow path of the fluid through a disconnect containing a closure is dependent upon the type of closure employed. Since the closure, by nature of its function, forms an integral part of the flow path, it must be considered with the flow area.

1.1.1 The design of the flow area will determine the pressure drop characteristics of the disconnect. There is no problem in current technology for design of the flow area. The design of the flow path for least pressure drop follows well known principles of fluid mechanics found in many published texts.

1.1.2 The closures used in disconnects manufactured by the vendors contacted were of two types, (a) poppet design and (b) butterfly.

1.1.2.1 Poppet Valve closures are uniquely adaptable because of geometry and motion to disconnects where fluid cut-off is required at disconnection.

1.1.2.2 Butterfly valve closures do not provide the uniform flow path which can be obtained with poppets, but are more readily adapted to remote actuation where a rotating shaft seal problem is not objectionable.

1.1.2.3 Disconnects employing poppets are shown in Figures 1-1, 1-2, 1-5 and 1-6 and Figure 1-3 shows a typical cross section of a poppet closure disconnect. Figure 1-4 shows a disconnect using a butterfly closure.

1.2 Disconnection Methods

Vendor research disclosed two main types of disconnect methods. Both types employ seals to prevent leakage upon disconnection. One type requires external restraint to maintain connection while the other depends upon an internal restraint between the disconnect halves to maintain connection.

1.2.1 External Restraint. This disconnect method consists of a probe and mating part employing a dynamic seal on a sliding surface. The engagement may be between concentric cylinders or between spherical surfaces. Figures 1-1, 1-4, 1-7, 1-8 and 1-9 are typical of concentric cylinder probes. Figure 1-2 shows a spherical surface probe. When used as rise-off disconnects, the ground portion is of heavy construction. Figure 1-9 shows a vehicle borne staging disconnect. In all cases, a structural restraint is available for each half of the disconnect.

1.2.2 Another type of internal restraint is obtained by using necked down tension bolts to hold the disconnect halves together. For separation, a tensile load is applied either by cam action initiated by a lanyard pull or by inducing a bending load also initiated by a lanyard pull. In each case, the bolts are failed in tension for separation. Examples are shown in Figures 1-5 and 1-7. Figure 1-6 shows ground half only.

1.2.3 A mechanical detent used for internally restrained types of disconnects is employed mainly in smaller sizes, up to approximately 3 inches in diameter. The disconnect consists of a probe sealed with an "O" ring as in larger sizes. An exception is the Snap-Tite line of disconnects using metallic seats, which also employ a bellows type of seal for the probe in order to eliminate all non-metallic parts. The most common form of detent is the ball and groove arrangement, whereby a cylindrical ball retainer on one side of the disconnect body, positions a row of steel balls which drop into a groove on the other side of the disconnect body. The balls are retained by a sliding collar. The two bodies of the disconnect are thus locked together since the cylindrical cage is restrained by the balls which are locked in the groove by the sliding collar. Figure 1-10 shows a typical disconnect of this type.

1.3 Actuator

Three categories of valve actuators are in common use in current technology. In each category, there is a broad range of configurations of which only a few typical examples are shown.

1.3.1 Mechanical Actuators.

a. Simple linear actuators are common in poppet type closures in which a suitably designed probe pushes the poppet open when the two halves of the disconnect are mated. Typical examples are shown in Figures 1-1, 1-2, 1-4 and 1-9.

b. Manual actuators may employ rotary motion to actuate a screw engagement or a lever to actuate a cam or shaft. See Figures 1-11 and 1-12.

1.3.2 Pneumatic actuators are adaptations of pneumatic cylinders to actuate a crank arm which turns a shaft to actuate a valve. Examples are shown in Figure 1-13. Pneumatic actuators may also be used to initiate disconnect.

1.3.3 Electric actuators are electric motor driven mechanical screw jack type rams used instead of a pneumatic cylinder. This type is currently employed on Atlas LOX Fill and Drain Valve.

1.4 Flexible Ducting

The flexible duct used in disconnect design is usually on the ground side. Since the connection to the disconnect is usually metal by requirement of the fluid, the flexible section is made of convoluted section of duct. Flexible ducting may be categorized into two general types:

1.4.1 Ground Anchored. This is the most common type of flexible section and is usually one of three types:

a) Two convoluted sections

1. Internally restrained by a single tie rod swivel mounted to a spider at each end. A typical example is the aft section of the LOX staging valve shown in Figure 1-9.

2. Externally restrained by three external tie rods. Figure 1-1 shows a typical example on the ground nozzle assembly.

b) One convoluted section encased in a tension carrying metal wire braided sleeve.

1.4.2 Vehicle Anchored. This flexible section consists of a relatively long piece of convoluted duct covered with tension carrying wire braided sleeve. This arrangement is required when the ground portion of the disconnect is anchored to the airborne portion, such as shown in Figure 1-5.

1.5 Seals

Only seals used for disconnect mating probes and for valve closures are considered here. Static seals are discussed in Section 3 and are not considered to be a major problem in current technology. The seals for probes and valve closures are dynamic seals involving linear sliding motion or repeated seating and unseating without relative motion between the valve closure face and the seat.

1.5.1 Non-metallic seals are used as mating seals for probes in all of the examples shown in Figures 1-1 through 1-10. In the larger sizes, lip seals are used predominantly, as these perform well in this application.

1.5.2 Metal to metal valve sealing has been used, notably in internal combustion engines. However, the effectiveness of sealing obtained in this application would not be adequate for the FLOX disconnect requirements. Service valves used in liquid fluorine storage and transfer systems employ metal to metal seals successfully. The condition of such valves when disassembled after service reveals plastic deformation of the sealing surfaces. This condition indicates excessively high seat stress to obtain sealing. Service valves are usually of small size and of heavy construction so that the high stresses resulting in high loads on component parts are tolerable.

1.5.2.1 A successful airborne valve is being produced by AiResearch for the Saturn V program. The details are not available for publication; however, the valve is a ball (or visor) type valve employing a lip type metal seal loaded by means of a short convoluted length of duct. Leakage rates are reportedly well within the limits of the FLOX disconnect requirements.

1.5.2.2 The ground side of a Centaur fill and drain valve is shown in Figure 1-6. The leakage requirement for this valve is not as rigid as required for the FLOX disconnects.

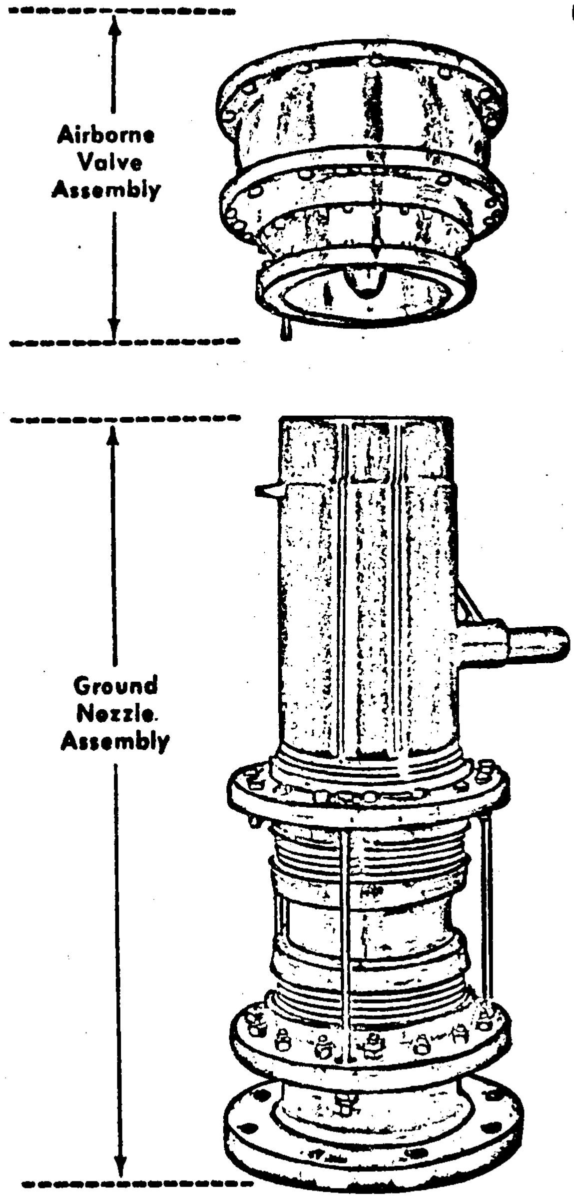
1.5.2.3 Snap-Tite, Inc. has a commercial line of manual disconnects ranging up to 3 inches diameter in size. These valves employ metal to metal seats which depend upon spring load to develop the seat stress adequate for sealing with essentially zero leakage. Construction details are not currently published.

1.5.3 Valve closures employing metal to metal seats are definitely within the range of current technology. However, the parameters for the successful design of any particular valve closure face and seat to obtain the low leakage rates required for the FLOX disconnect will need to be developed because of the lack of applicable parametric data.

6" LOX & FUEL FILL & DRAIN SYSTEM

FOR USE AT CRYOGENIC TEMPERATURES

includes
- Airborne Valve Assembly
- Ground Nozzle Assembly



FUNCTION:

The 6" LOX and Fuel system is designed for use in filling and draining missiles with cryogenic or hydrocarbon fuel at the rate of 1,500 gpm. It compensates for misalignment between the missile and the ground fuel systems, and provides for disengagement of the missile from the ground supply upon lift-off, with automatic, positive sealing of the missile tank upon disengagement.

DESCRIPTION:

The system consists of an airborne valve assembly which is bolted to the missile structure, and a ground nozzle assembly which is fixed to the fuel supply system on the launching pad. The airborne valve contains a spring loaded poppet, and a flexible, self-energized lip seal in the intake end. While the airborne valves for fuel and LOX are identical, separate model numbers are assigned to prevent inadvertent use of a fuel contaminated valve in a LOX system. The ground nozzle assembly consists of a nozzle probe and a flexible bellows section.

FEATURES:

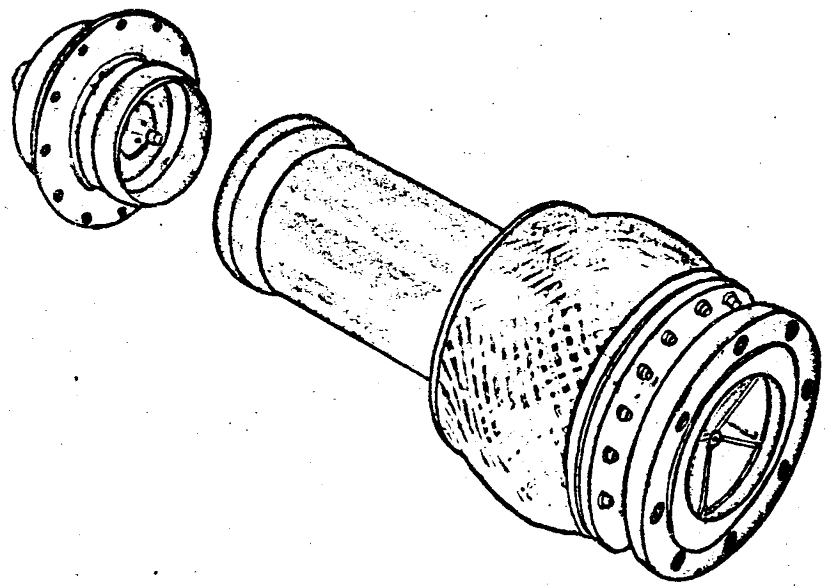
Low leakage at cryogenic temperatures
Simplicty and reliability
Low pressure drop
Fully proved flight article on an IRBM

OPERATION.

For the filling or draining operation, the airborne valve is engaged with the nozzle probe when the missile is on the pad. As the probe inserts into the valve and contacts the flexible lip seal, a sliding seal is formed before the probe lifts the poppet off its seat. The pressure-energizing feature of this lip seal permits operation at cryogenic temperatures. The poppet is held open while the valve and probe are engaged. The bellows section of the ground nozzle assembly compensates for misalignment between the missile and the ground fuel feed system without affecting the system pressure drop. Total pressure drop is less than 5 psia at 1,500 gpm of water. Leakage through the sliding seal formed between the nozzle probe and the airborne valve is 3 cc liquid per minute maximum at pressures up to 85 psi.

Spring and fuel tank pressures seat the poppet when the missile lifts off the pad and the probe is disengaged. Maximum leakage from the missile tank with the poppet closed is 3 cc liquid per minute.

FIGURE 1 - 1



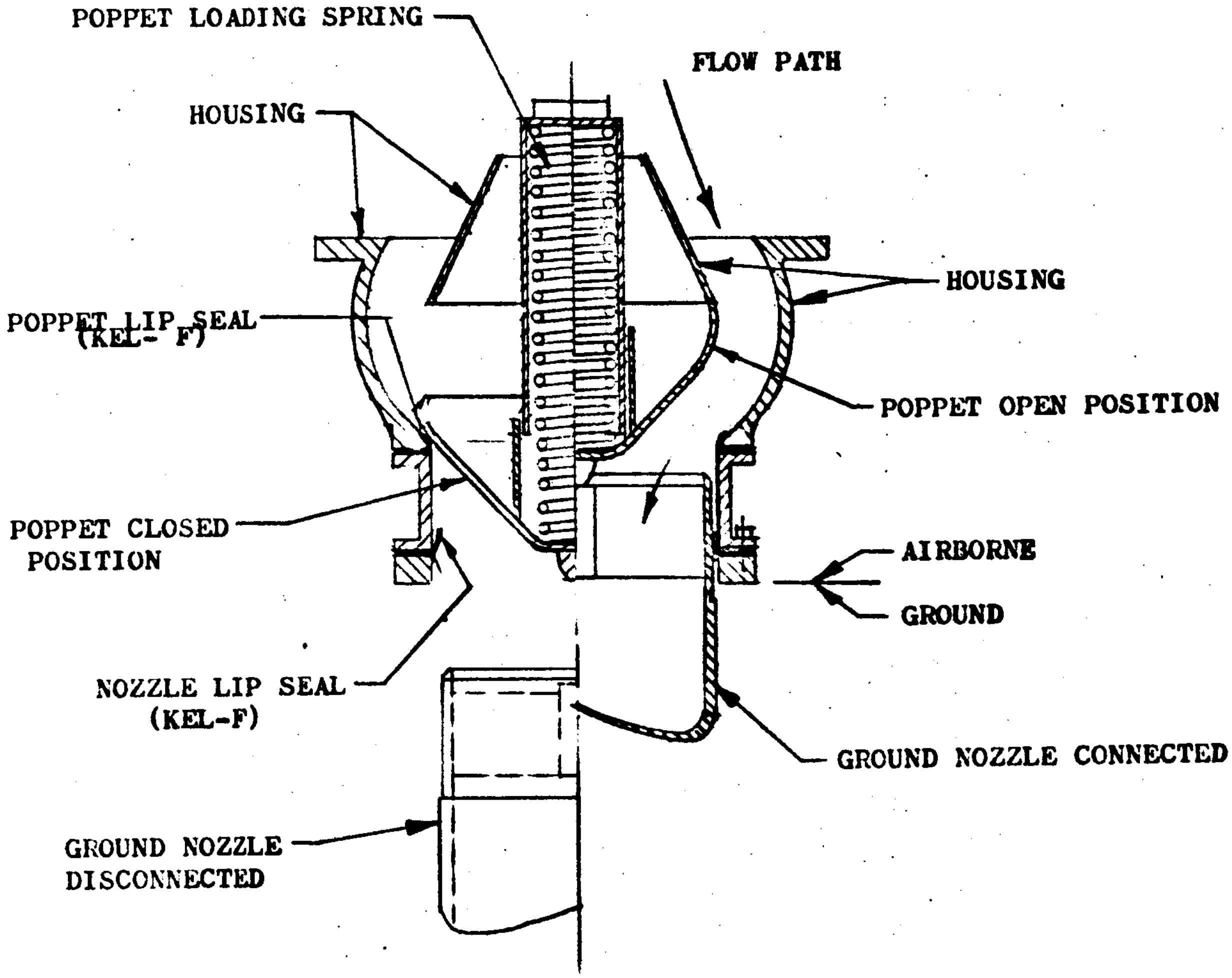
DESCRIPTION:

This unit is designed specifically to handle the RP-1 fuels at ambient temperatures, and liquid oxygen in the cryogenic range. In a single design it will satisfy requirements for both fill and drain. The valve portion is a permanent part of the missile. Separation takes place during launch.

SPECIFICATIONS:

Size (ID of flow passage)	6 inch
Weight	
Missileborne valve	8.32 lbs.
Ground half	56 lbs.
Temperature Range	-324°F to 160°F
Misalignment during engagement	
Angular	$\pm 10°$
Linear	$\pm \frac{1}{2}$"
Fluids	RP-1 Liquid Oxygen Liquid Nitrogen
Flow Rate	1500 GPM
Pressure Loss (RP-1 Fuel)	6.5 psi

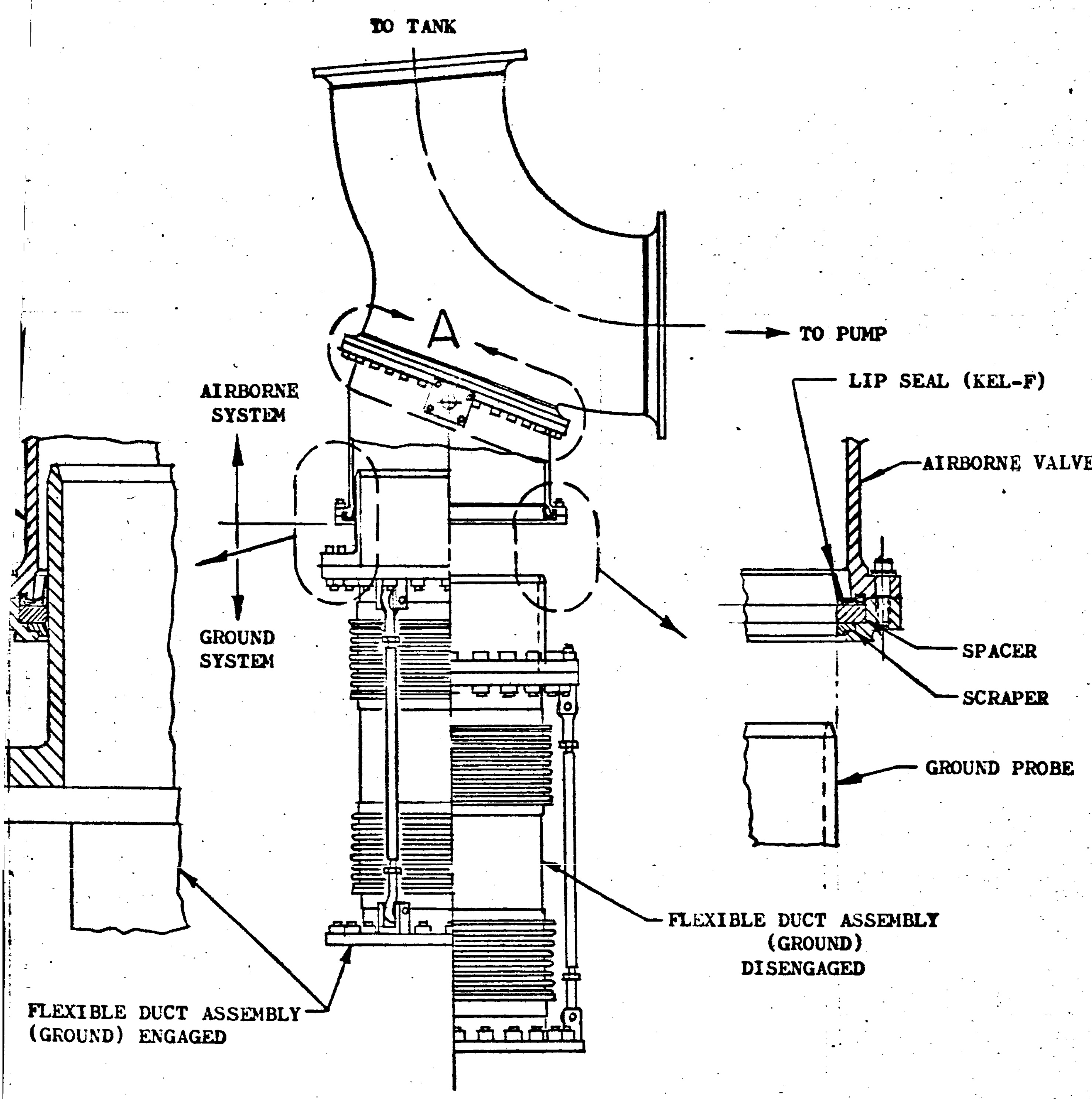
FIGURE 1 - 2



6" FILL & DRAIN VALVE

FOR LOX SERVICE

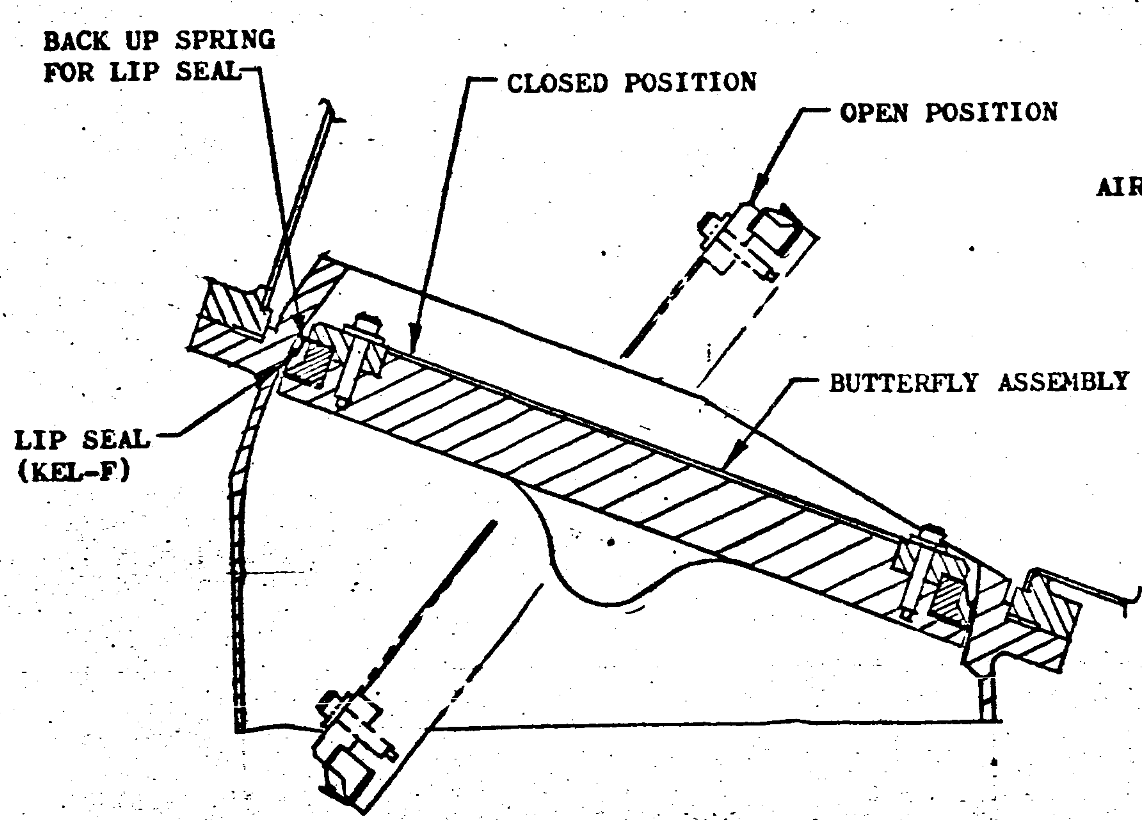
FIGURE 1-3



LOX FILL & DRAIN VALVE

7 inch inside diameter at each outlet

FIGURE 1-4



DETAIL A
SHOWING SECTION THRU BUTTERFLY

AIRBORNE

FLEXIBLE ASSEM
(GROUND)

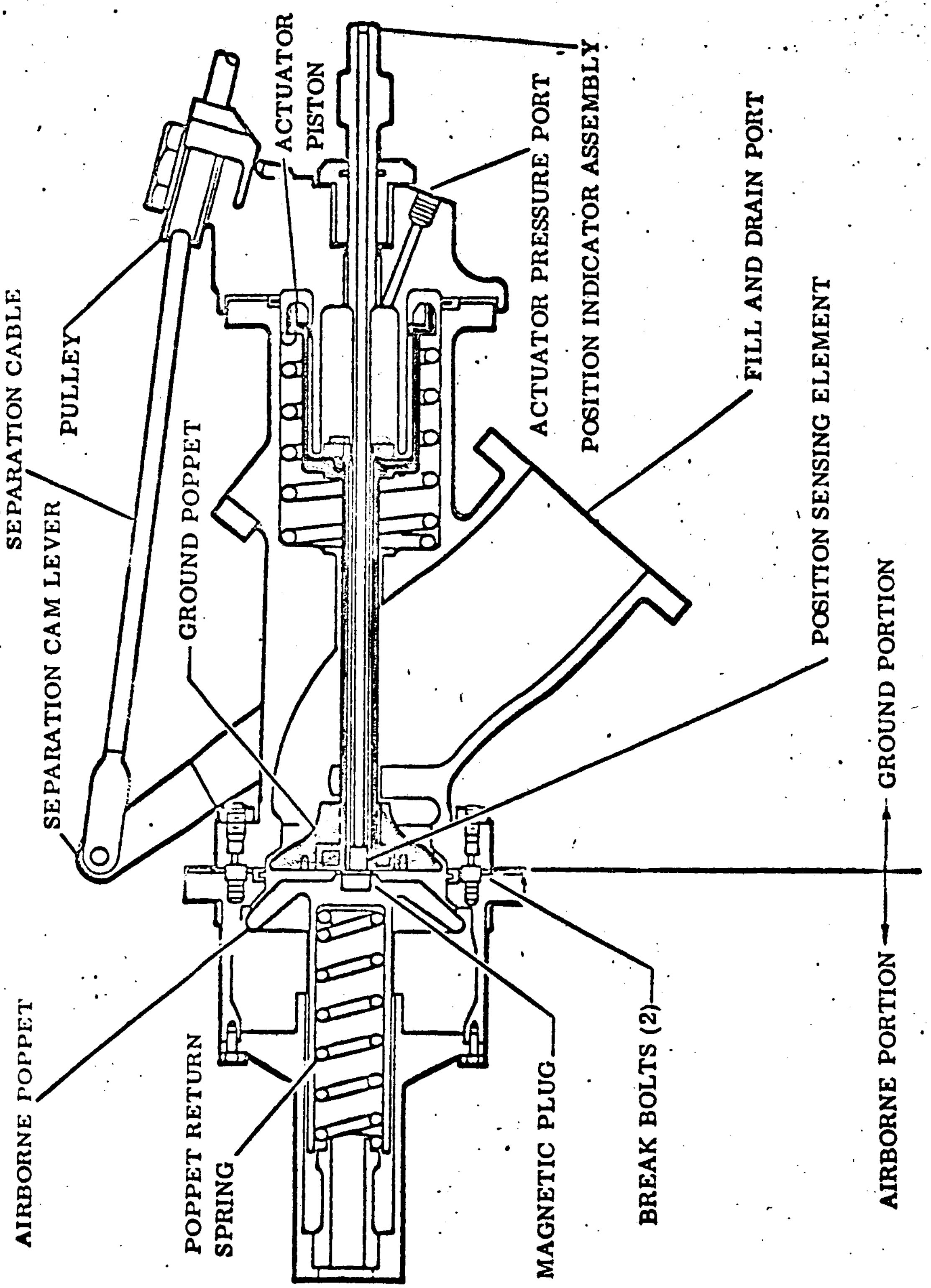


Figure 1-5 Liquid oxygen and liquid hydrogen fill-and-drain valve.

COMPLEX 36B GROUND FILL/DRAIN VALVE

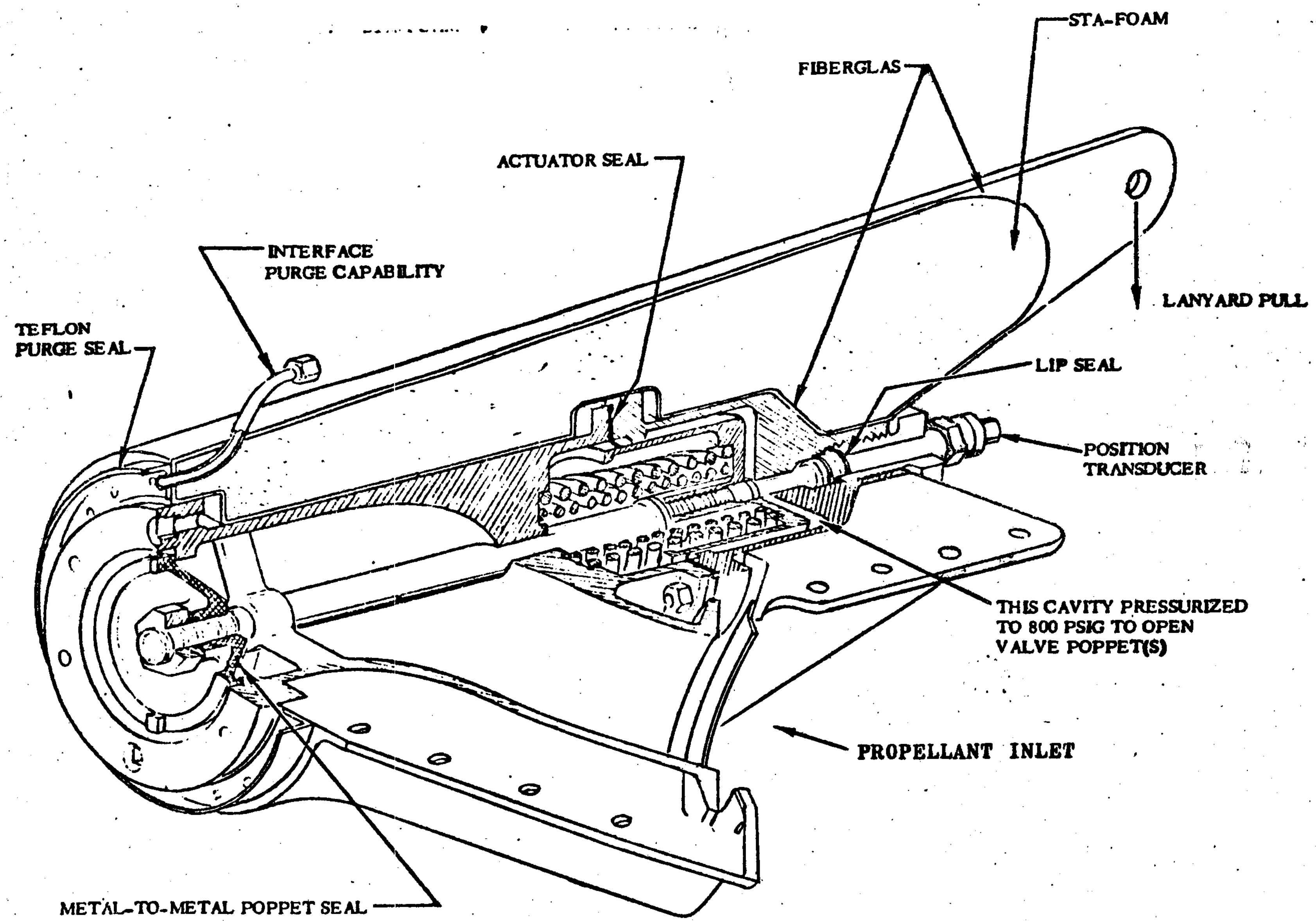


FIGURE 1-6

AC-2 THRU AC-5 LIQUID HELIUM UMBILICAL DISCONNECT

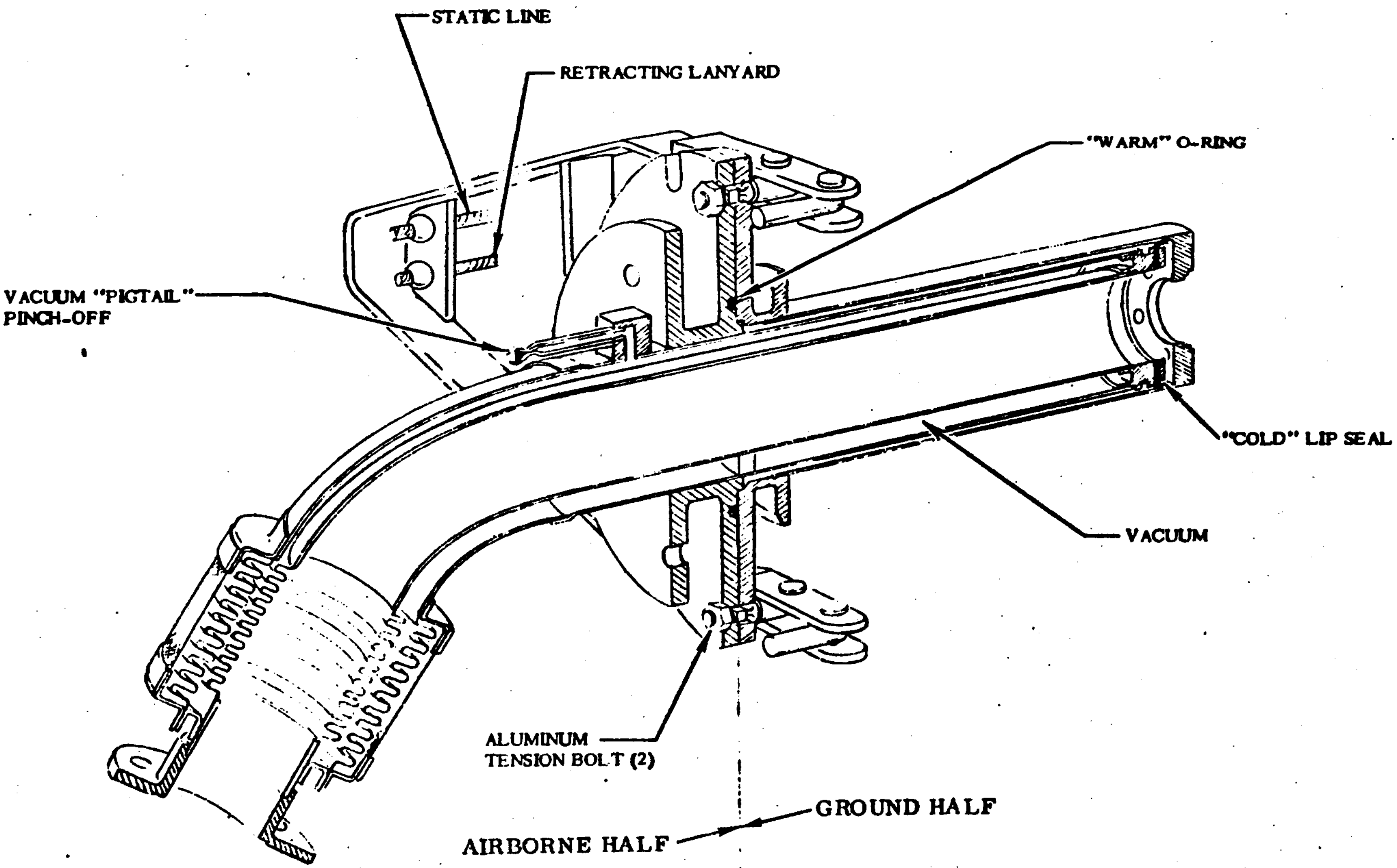


FIGURE 1-7

10-42

AC-6 LIQUID HELIUM UMBILICAL DISCONNECT

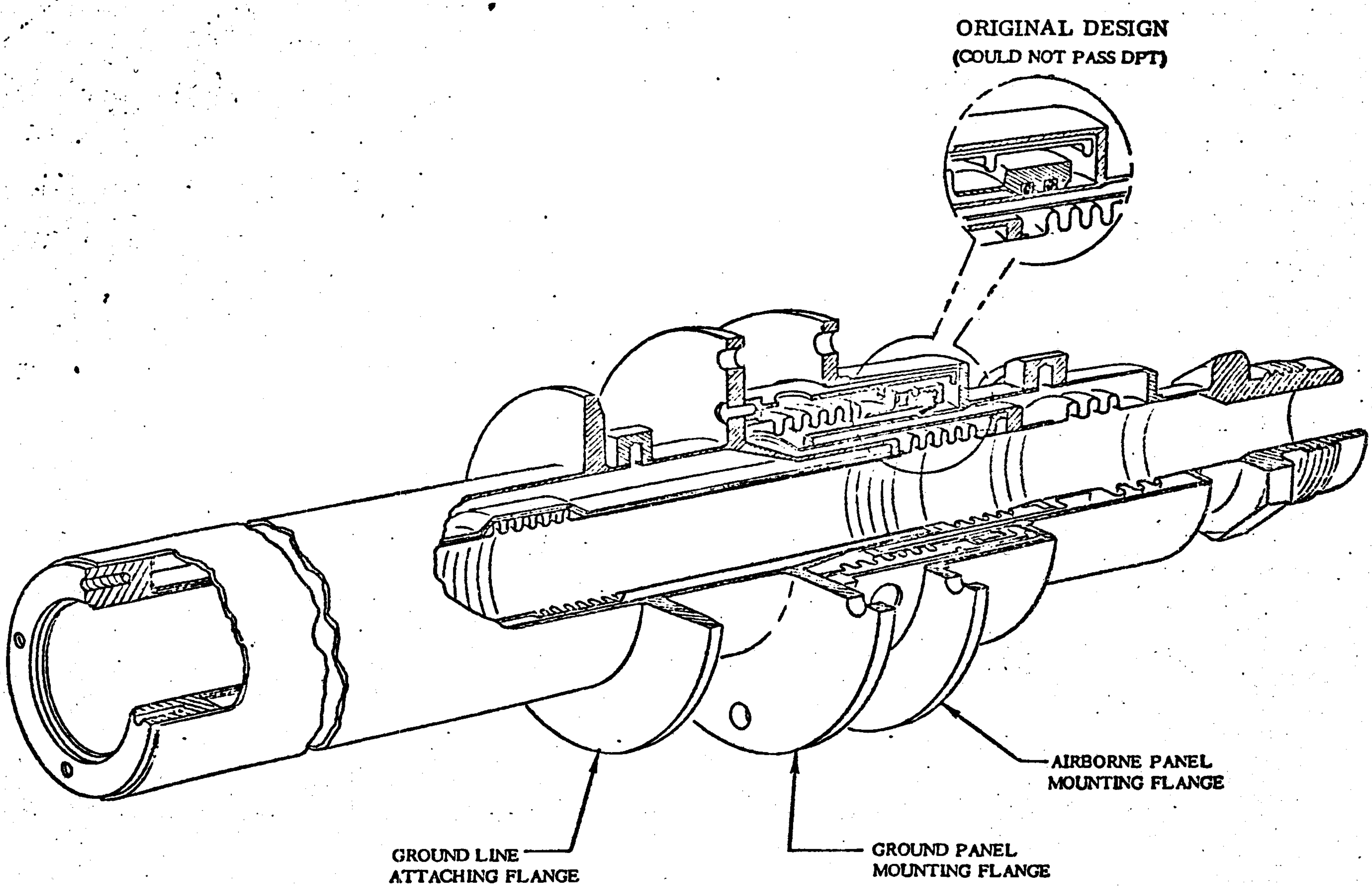


FIGURE 1-8

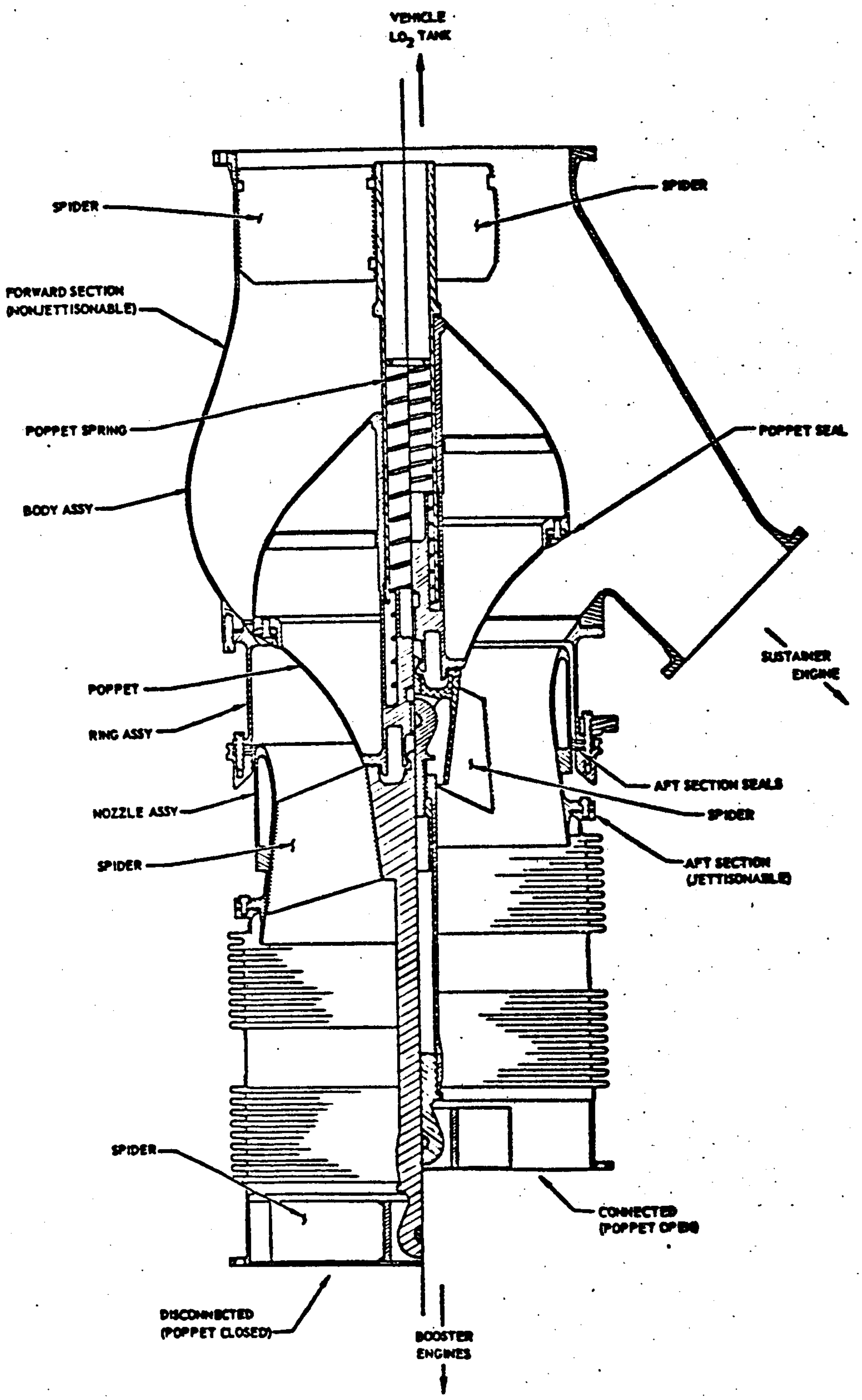
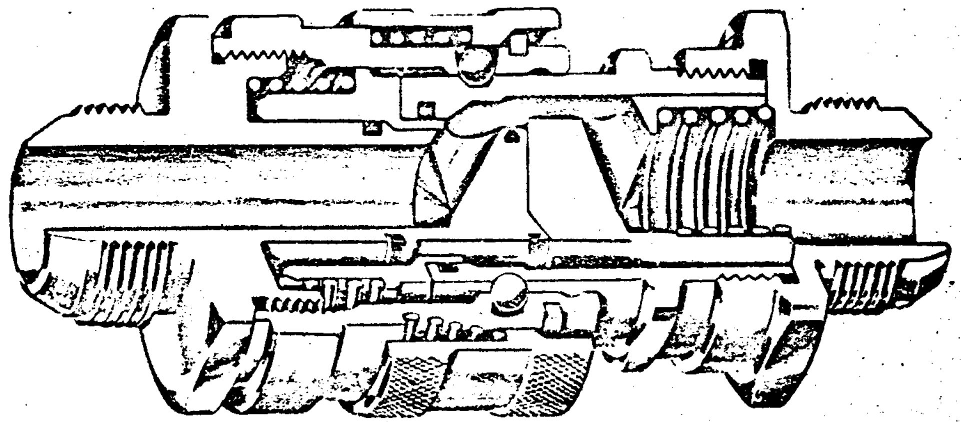
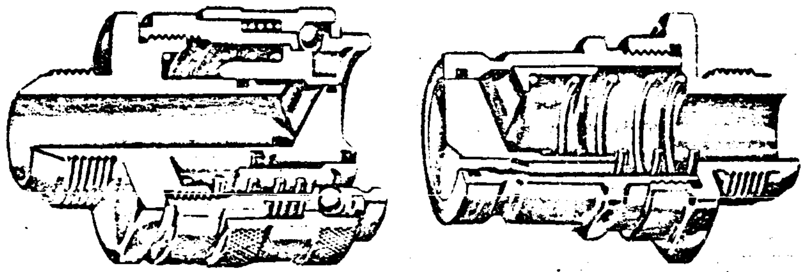


Figure 1-9 Booster Liquid Oxygen Disconnect-Valve **Assembly**



CROSS SECTION OF CONNECTED COUPLING

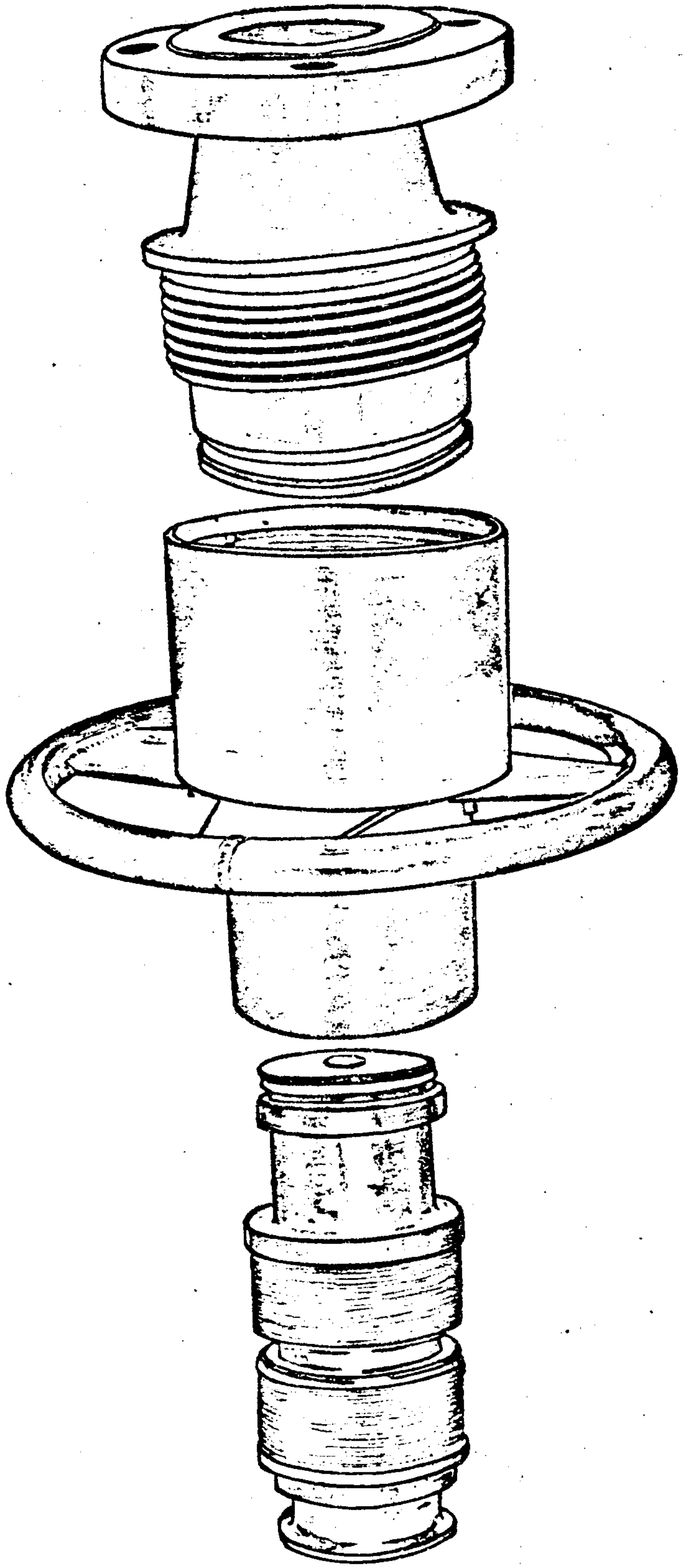


CROSS SECTION OF DISCONNECTED COUPLING

TYPICAL INTERNALLY RESTRAINED DISCONNECT COUPLING

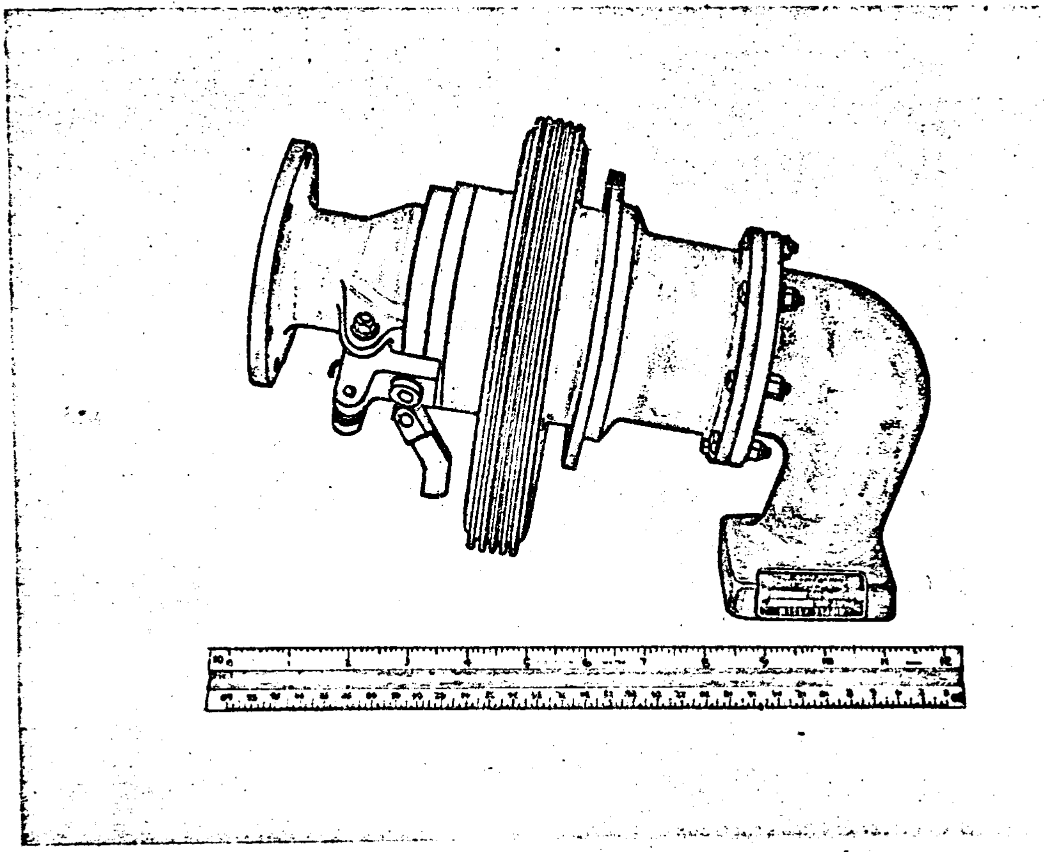
Courtesy SNAP- TITE, INC.

FIGURE 1-10



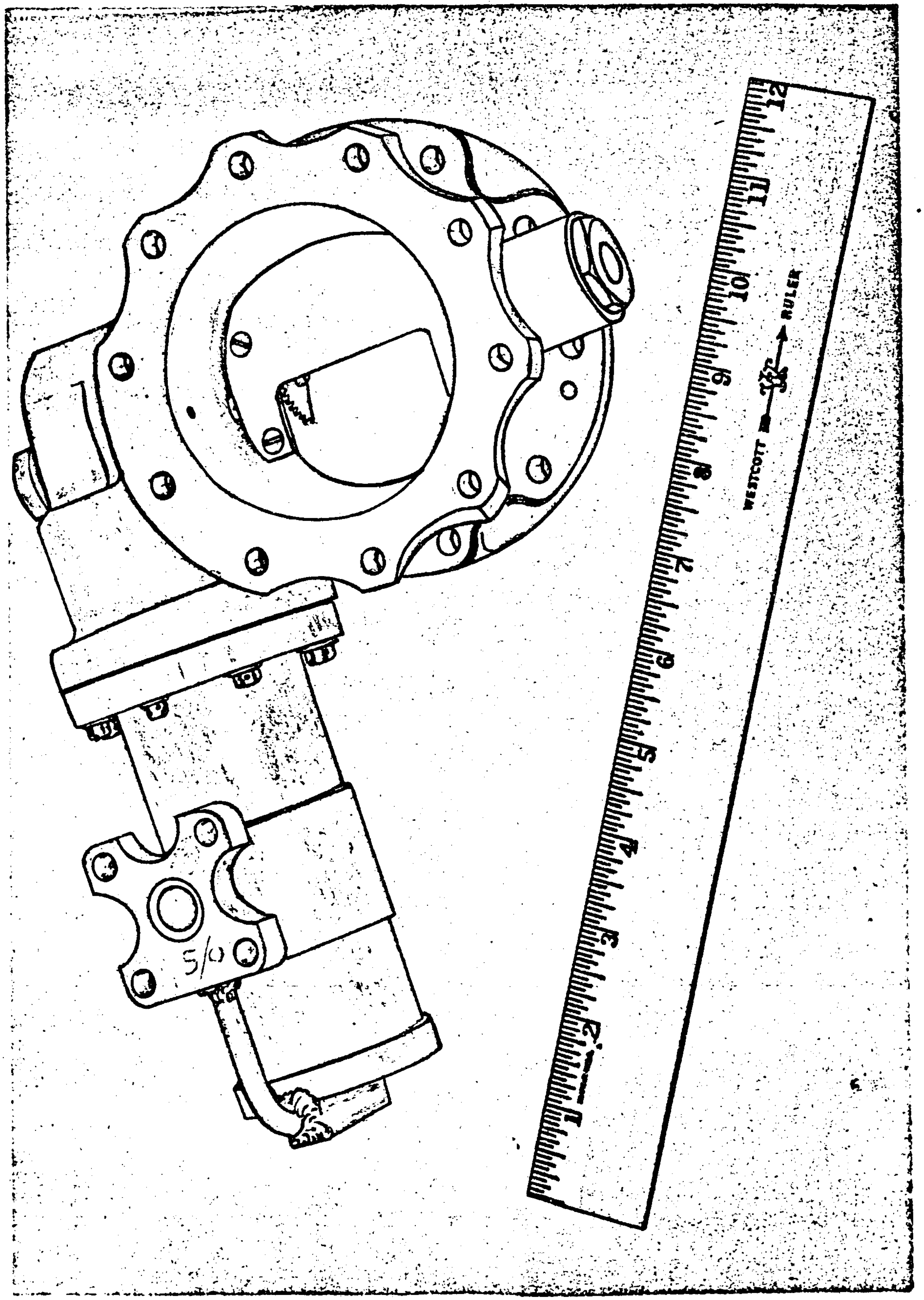
3 inch
Manual Fuel Disconnect

FIGURE 1 - 11



ASSEMBLY:	1039
SIZE:	2 Inch
COUPLING MATERIAL:	Aluminum Alloy 356-T6 castings with Steel, Electroless Nickel and/or Hard Chrome Plated, linkage
SEAL MATERIAL AND CONFIGURATION:	Minnesota Compound 366-Y—Snap-Tite's special design "Face Seal" for nipple Precision Compound 142-70—"O" Rings for adaptors and valves
DESIGNED FOR:	Pressure fueling the fuel system using aircraft turbine and jet engine fuels, Grade JP-3, JP-4 and JP-5. Operating pressure: 100 PSI Proof pressure: 200 PSI Temperature (*nipple*): —65°F to +200°F (*coupler*): —65°F to +135°F This unit involves three separate operations: 1. Manually connecting the coupler and nipple together. 2. Manually opening the valves by means of a handle. 3. Lanyard release which closes the valves and disconnects the coupler from the nipple in one operation.
BASIC DESIGN:	Manually connected, lanyard disconnected No Spill
COUPLER WEIGHT:	4½ Lbs.
NIPPLE WEIGHT:	2¼ Lbs.

FIGURE 1 - 12



3" LOX and Anhydrous Ammonia Valve - Experimental Airplane

FIGURE 1 - 13

2.0 PERFORMANCE SPECIFICATIONS

The following reproduced document specifies the design criteria and establishes the basic requirements of the FLOX Disconnect Valves.

PERFORMANCE SPECIFICATION

FLOX DISCONNECT

FOR A FLOX-ATLAS VEHICLE

Preliminary Design
Specification

10 June 1965

Contract Number NAS3-3245

TCP 8436   NASA/LeRC

Task Order #3

Prepared By: E. L. Holston

Approved By: E. J. Hujsak
Ass't Chief Engineer
Propulsion Design

Approved By: W. A. Roberts
Ass't Project Engineer
FLOX-Atlas

General Dynamics/Convair
A Division of General Dynamics Corporation
San Diego, California

ABSTRACT

This document describes the performance specifications for a multiple purpose disconnect which shall replace the existing LOX fill and drain disconnect and LOX staging disconnect when the LOX-Atlas oxidizer system is used for the FLOX-Atlas vehicle. In addition it shall serve as the FLOX peculiar boil-off disconnect. Thus the disconnect shall serve the triple purposes of oxidizer fill and drain rise-off disconnection, oxidizer interstage disconnection and boil-off disconnection. Design of the component for application in any of the three locations requires that it shall meet the most severe design requirements of each location.

PERFORMANCE SPECIFICATION

FLOX DISCONNECT

FOR A FLOX - ATLAS VEHICLE

1. INTRODUCTION

1.1 Scope

This document specifies the design criteria for the FLOX disconnects at lift-off and staging and establishes the basic capabilities of the components to perform their functions. It shall serve as the internal control for design to these requirements to maintain compatibility with requirements of the propulsion system. The components governed are:

A. Oxidizer boil-off disconnect.

B. Oxidizer interstage disconnect.

C. Oxidizer fill and drain disconnect.

The release of this document establishes the requirements which all three units shall meet.

1.2 Applicable Documents

In addition to the requirements stated herein, the components shall also be designed to conform to the general requirements specified in the documents listed below:

A. Military Specifications

MIL-F-7179(1)	Finishes and Coatings; General Specification for Protection of Aircraft and Aircraft Parts
MIL-E-5272A 16 September 1952	Environmental Testing, Aeronautical and Associated Equipment
MIL-N-6011 14 March 1950	Nitrogen; Gas and Liquid

B. Military Standards

C. Publications

Air Force - Navy-Aeronautical Bulletins:

143d 19 August 1954	Specifications and Standards, Use of

1.2 C. Publications - Continued

Contractor

0-75002	Cleaning Procedures - Liquid Oxygen System Components
0-75019	Packaging of Missile System Components
7-00209B	Environmental Design Conditions and Environmental Test Procedures for WS-107A-1 Equipments, Specification for
69-00202B	Environmental Design and Test Criteria Specification for Space Launch Vehicles Vehicleborne and Aerospace Ground Equipment.

2. REQUIREMENTS

2.1 Design Requirements - General

2.1.1 Basic Unit - One basic unit containing a closure device which remains open when connected and closes and seals either liquid or gas when disconnected shall be the basic unit. This unit shall be so designed that when a closure is required on both sides of a disconnect, two basic units essentially identical will be used in tandem to satisfy the requirements

2.1.2 Materials - Materials used shall be compatible with liquid oxygen and liquid flourine in any mixture ratio. (FLOX)

2.1.2.1 All materials in contact with FLOX must be metals which are compatible with FLOX. (All seals in particular)

2.1.2.2 Leakage - The design must provide for no external leakage from the unit body or from engaged units up to proof press.

2.1.2.3 Decontamination Requirements - Prime consideration in design shall be given to provide for ease of cleaning, purging and contamination control.

2.1.2.4 Environmental Requirements - The design shall conform to environmental requirements per GD/C Report 69-00202B, 21 January 1964.

2.1.2.5 Lubrication - The component shall be designed to function properly without lubrication of any parts and/or assembly.

2.1.2.6 Screw Threads - There shall be no screw threads exposed to FLOX.

2.1 Design Requirements - General - Continued

2.1.2.7 Joining - The design shall provide for welding in preference to brazing; however, brazing is not prohibited.

2.1.2.8 Weight - Good design practices shall be employed to provide minimum weight.

2.1.2.9 Interfaces and Clearance Envelopes - Prime consideration shall be given to matching existing interfaces and holding to existing clearance envelopes for the Atlas-Centaur vehicle.

2.1.2.10 FLOX Entrapment - When double closure disconnects are employed, the space between the closures shall be a minimum.

2.1.3 Concept of Installation Modes - The basic unit may be used in three different installation modes. These are shown schematically in Figure 1. Figure 1A shows the unit installed as a disconnect downstream from the boil-off valve. An alternate to 1A would be to install the boil-off valve on the ground and let the unit be the primary shut-off for the tank vent system. Figure 1B shows the unit installed as a staging disconnect and Figure 1C shows the unit installed as the fill and drain disconnect.

2.1.3.1 Installation Mode Requirements

2.1.3.1.1 Boil-Off Valve Vent Disconnect

a. Separate closures in both ground and airborne halves of the disconnect shall be provided.

b. Structural integrity of the tank shall not be jeopardized by allowable leakage from the airborne closure after separation (applicable for case where boil-off valve will be located on ground).

c. Both closures shall open and remain open when connected, and shall close and remain closed when disconnected and closures shall remain closed while separation seal is disengaged.

2.1 Design Requirements - General - Continued

2.1.3.1.2 Oxidizer Interstage Disconnect -

a. Separate closures in both the sustainer half and booster half shall be provided.

b. In the mated position, the closures in each half shall remain open until demated.

c. Upon demating closures in each half shall close and seal before separation seal is disengaged.

2.1.3.1.3 Oxidizer Fill and Drain Disconnect -

a. Separate closures shall be provided in both the airborne and the ground portion of the disconnect.

b. A provision shall be incorporated to remotely actuate the closure to fully open or fully closed position. Closure actuator and indicators shall be incorporated in the ground portion of the disconnect.

c. The position indicator shall indicate the true position of closure, not of actuator.

d. Disconnection shall occur from vehicle rise-off motion.

3. PERFORMANCE REQUIREMENTS

3.1 Working Fluid

The unit(s) shall be designed to function with the following fluid media.

3.1.1 Liquid FLOX - Liquid oxygen and liquid flourine mixed in any proportion from 100% liquid oxygen to 100% liquid flourine.

3.1.2 Gaseous FLOX - Gaseous oxygen and gaseous flourine mixed in any proportion from 100% gaseous oxygen to 100% gaseous flourine.

3.1.3 Helium - The unit closure shall seal against helium to the limits shown.

3.2 Operating Temperature

3.2.1 For Liquid FLOX -320° F to -280° F

3.2.2 For Gaseous FLOX -300°F to +500°F

3.3 Design Pressures

3.3 Design Pressures - Continued

3.3.1 For Liquid FLOX

a. 117 psi operating

b. 178 psi proof

c. 228 psi burst

d. The surge pressure developed at vehicle staging will not exceed proof pressure.

3.4 Flow Requirements

3.4.1 Oxidizer Interstage Disconnect

3.4.1.1 The component shall be designed to flow 5320 gpm to the booster engine while connected at an inlet pressure of 67 to 117 psig. The pressure drop to the booster engine outlet of the component shall not be more than 5.0 psi.

3.4.1.2 During tanking operation, with flow in the opposite direction the unit shall have a flow capacity of 2000 gpm with a pressure drop across the unit not exceeding 8 psi.

3.4.2 Oxidizer Fill and Drain Component

3.4.2.1 The pressure drop across this component consisting of two basic units, valve actuator and flexible ground connection adapter with a tanking flow rate of 2000 gpm shall not exceed 4.0 psi.

3.4.2.2 The pressure drop across this component for draining operation at a flow rate of 4000 gpm shall not exceed 15 psig.

3.4.3 Oxidizer Boil-Off Disconnect

3.4.3.1 The two connected basic units shall be capable of flowing 15 lbs/sec of gaseous FLOX @ -290° F with a pressure drop not exceeding 2 psig.

3.5 Closed Leakage

3.5.1 Liquid FLOX Leakage - In the drain configuration (Figure 1) with the closure closed to prevent flow in the drain direction, liquid leakage past the closure seal shall not exceed 1 cubic inch per minute for any pressure up to proof pressure.

3.5.2 Gaseous Leakage - In the drain configuration (Figure 1) with the closure closed to prevent flow in the drain direction, helium or gaseous FLOX leakage past the closure seal shall not exceed 263 SCIM at 32 psig.

4. ENVIRONMENTAL REQUIREMENTS

4.1 General

The requirements of GD/A Report 69-00202B shall apply to the Basic Units and the component assemblies and/or installations of which they are a part, except as noted in par. 4.2, 4.3 and 4.4 below.

4.2 Storage and Transportation Environments

The Basic Units and the assemblies and/or installations of which they are a part shall be capable of safe storage and transportation without impairment of capabilities from the effects of non-operating environments specified in GD/A Report 7-00209B, par. 3.2.

4.3 Thermal Environment

4.3.1 Oxidizer Fill and Drain Actuator and Ground Flexible Section

These components shall be capable of withstanding the thermal effects of rocket engine blast to the following extent:

Temperature	Velocity	Time
50,000 BTU/Ft^2/Min 5,000° F	5,000 Ft/Sec	3 Seconds

4.4 Vibration

This vibration envelope was selected because experience and test data had shown that the previously used specification GD/A 69-00202B was too strenuous and was subjecting the components to vibration beyond their actual use.

5. LIMITATION

5.1 Basic Unit

5.1.1 Weight

a. Dry weight 25 pounds
b. Wet weight 95 pounds

5.1.1.1 Oxidizer Fill and Drain Actuator Section

5.1.1.1.1 Weight

a. Dry weight 25 pounds
b. Wet weight 25 pounds

5.1.1.2 Oxidizer Fill and Drain Ground Flexible Section

5.1.1.2.1 Weight

a. Dry weight Not critical

5.1.2 Size

5.1.2 Size - The units shall be designed within the following size envelopes.

5.1.2.1 Basic Unit - Maximum basic diameter 16 inches

5.1.2.2 Oxidizer Interstage Disconnect

Maximum Diameter	16 inches
Maximum Length	33 inches
Longitudinal Flexibility	±.2 inches
Lateral Flexibility, any direction	±.35 inches
Angular Misalignment	1.5 degrees

5.1.2.2.1 Deformation - If constructed of convoluted flexible sections, the Flexible Section shall be designed to prevent excessive permanent set or squirming to the extent that the performance of its function may be impaired. Minor permanent set normally prevalent as a result of manufacturing limitations or acceptance testing which obviously will not affect performance of function shall be acceptable. Upon development of a satisfactory part, the primary parameter for acceptance of subsequent parts shall be repetition of the spring rate within ± 5%.

5.1.2.3 Oxidizer Fill and Drain Ground Flexible Section

Maximum Diameter	16 inches
Maximum Length	Practical Minimum inches

5.1 Basic Unit - Continued

5.1.2.3 Oxidizer Fill and Drain Ground Flexible Section - Continued

Axial Flexibility	± 1.0 inches
Lateral Flexibility at Stub-up in any direction	± .60 inches
Angular Misalignment	1.5 degrees

5.1.2.3.1 Deformation - If constructed of convoluted flexible sections, the Flexible Section shall be designed to prevent excessive permanent set or squirming to the extent that the performance of its function may be impaired. Minor permanent set normally prevalent as a result of manufacturing limitations or acceptance testing which obviously will not affect performance of function shall be acceptable. Upon development of a satisfactory part, the primary parameter for acceptance of subsequent parts shall be repetition of the spring rate within ± 5%.

5.1.2.4 Oxidizer Fill and Drain Actuator Section

Maximum Diameter		11 inches
Minimum Diameter		6 inches
Maximum Length		Practical Minimum inches
Actuator Housing:	Height	6 inches
	Width	17 inches
	From ℄ Duct	10 inches

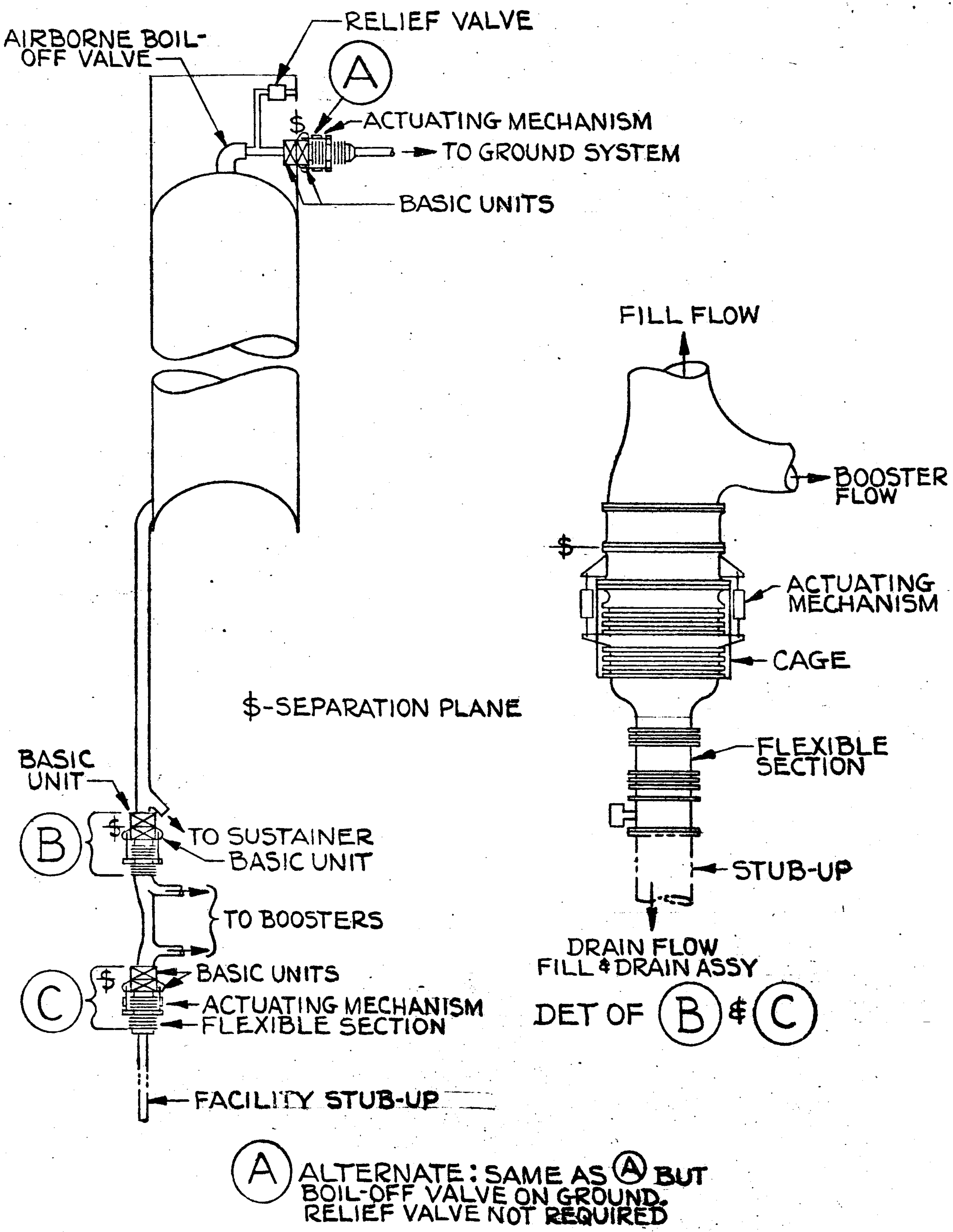

RELIEF VALVE
AIRBORNE BOIL-OFF VALVE
A
$
ACTUATING MECHANISM
TO GROUND SYSTEM
BASIC UNITS
FILL FLOW
BOOSTER FLOW
$
ACTUATING MECHANISM
CAGE
$-SEPARATION PLANE
FLEXIBLE SECTION
BASIC UNIT
B
$
TO SUSTAINER
BASIC UNIT
STUB-UP
TO BOOSTERS
DRAIN FLOW
FILL & DRAIN ASSY
C
$
BASIC UNITS
ACTUATING MECHANISM
FLEXIBLE SECTION
DET OF B & C
FACILITY STUB-UP
A ALTERNATE: SAME AS A BUT
BOIL-OFF VALVE ON GROUND.
RELIEF VALVE NOT REQUIRED

FIG. 1

UNIVERSAL VALVE RANDOM VIBRATION REQUIREMENTS

(FOR COMBINATION WITH SINUSOIDAL VIBRATION)

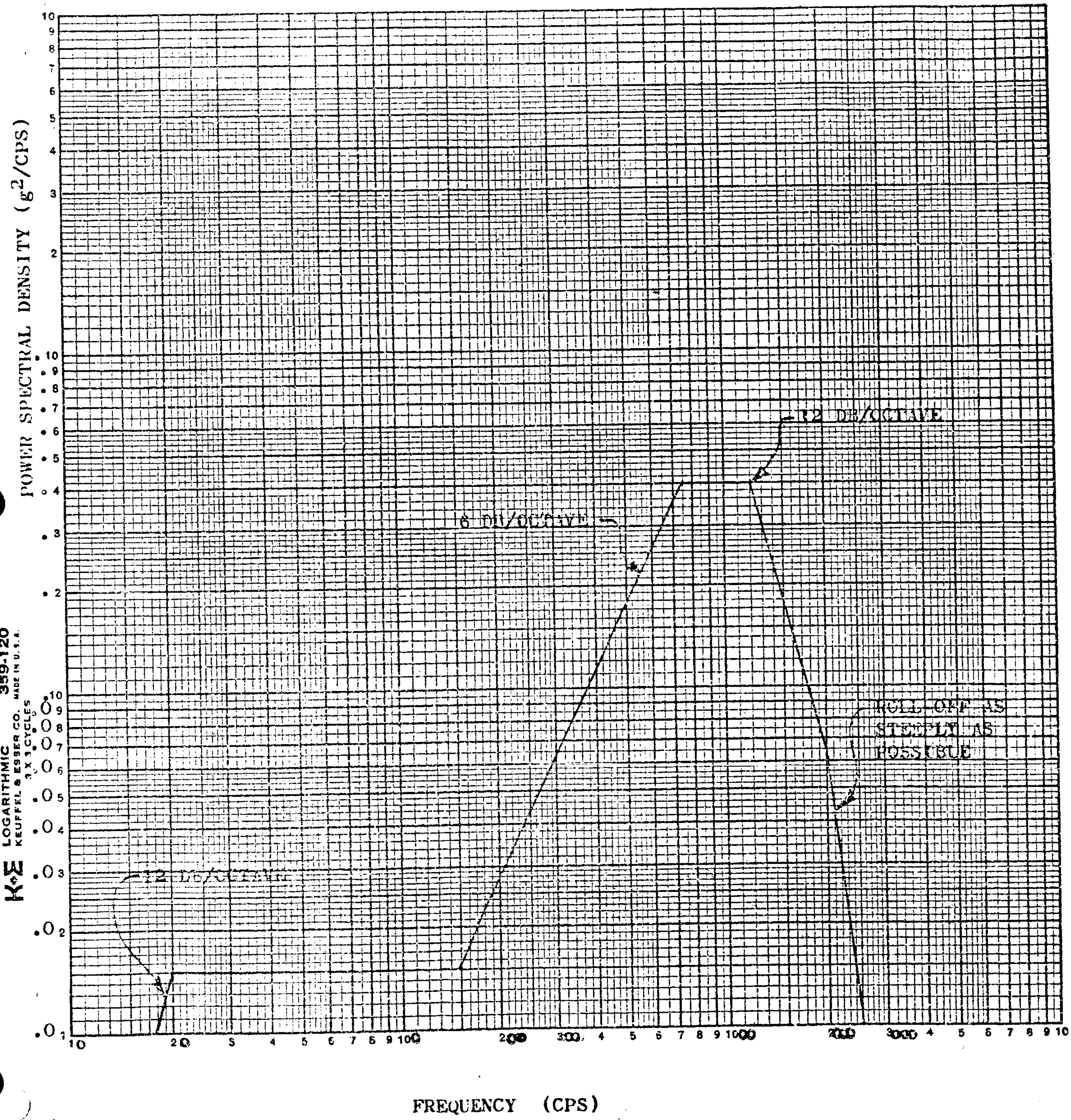


FIG. 2

JS 6/14/65

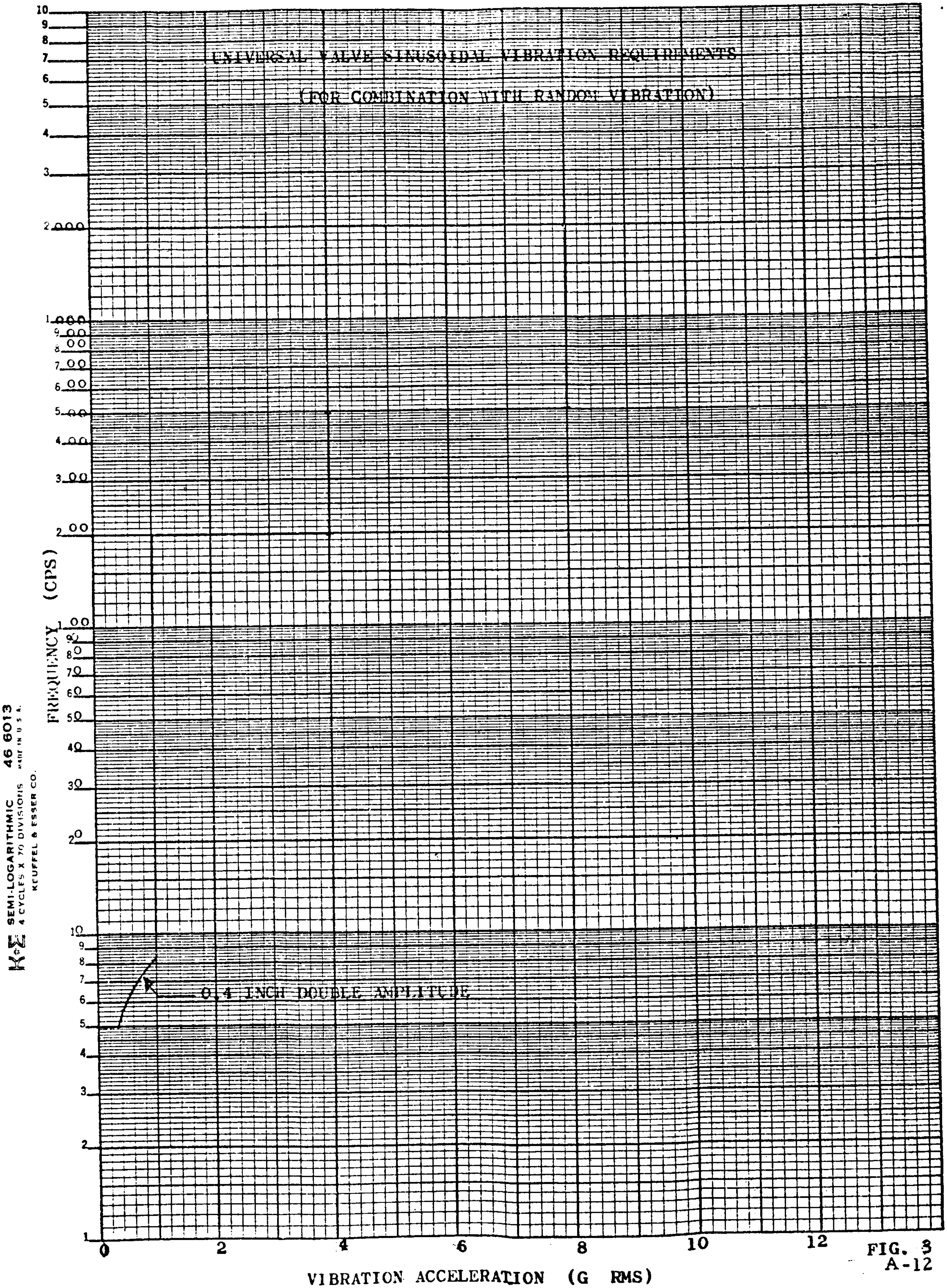

UNIVERSAL VALVE SINUSOIDAL VIBRATION REQUIREMENTS
(FOR COMBINATION WITH RANDOM VIBRATION)
0.4 INCH DOUBLE AMPLITUDE
FREQUENCY (CPS)
VIBRATION ACCELERATION (G RMS)
0
2
4
6
8
10
12
1
2
3
4
5
6
7
8
9
10
20
30
40
50
60
70
80
90
1,00
2,00
3,00
4,00
5,00
6,00
7,00
8,00
9,00
1,000
2,000
K&E SEMI-LOGARITHMIC 46 6013
4 CYCLES X 70 DIVISIONS MADE IN U.S.A.
KEUFFEL & ESSER CO.

FIG. 3

A-12

3.0 CONCEPTUAL LAYOUTS AND EVALUATION

The FLOX-Disconnect was divided into its six different functions - the flow area and closure, disconnect area, actuator, indicator, flexible ducting, and seals required. Ideas are portrayed for each function. These ideas are rated excellent, good, fair, or poor in Figures 3.1, 3.2, 3.3, 3.4, 3.5, 3.6 and 3.7 to determine the best concept for an integrated valve design. There are four evaluation categories as enumerated below.

Fluorine Compatibility

a. Cleaning
b. Passivation
c. Inspection
d. Materials
e. Contamination Control
f. Leakage

Vehicle Compatibility

a. Envelope
b. Weight
c. Minimum Spillage
d. Universal usage

Reliability

a. Simplicity
b. Present Technology
c. Development Risk

Test

a. Qualification
b. Acceptance

3.1 Flow Area and Closure

The flow area shall be of such a size as to permit a flow of FLOX to the booster turbopumps at flow rates and pressure drops that do not adversely affect turbopump output. The required FLOX flow is approximately 5320 GPM at a minimum inlet pressure of 67 psi. The maximum pressure drop at the booster engine outlet shall not exceed 5 psi.

During tanking, a flow capacity of 2000 GPM with a maximum pressure drop of 4.0 psi shall not be exceeded.

3.1 Flow Area and Closure - Continued

For the draining condition, a flow rate of 4000 GPM and a maximum pressure drop of 15 psi is required.

The oxidizer boiloff disconnect must be capable of flowing 15 lbs/sec. of gaseous FLOX at -290° F with a pressure drop not exceeding 2.0 psi.

The flow area and closure evaluation ratings have been tabulated in Figure 3.1 for comparison of the various types and cases. A scale sketch of each case is followed by a letter indicating the degree of desirability.

A discussion of the principal merits and deficiencies of each case, with appropriate recommendations, is included in the following paragraphs.

3.1.1 Twin Butterfly. The twin butterfly closure consists of two closure leaves. The centerline of closure pivots are located so that leaves are parallel to each other in the open and closed positions and nearly parallel in the intermediate positions. Actuation is by a control rod to one leaf.

The twin butterfly closure offers the advantage of reasonable flow path conditions, adaptability to staging, vent and fill and drain uses; low air-borne residuals when used in the fill and drain application and minimum parts in the flow area. This type of unit can be designed within compact envelopes. The principle, however, does not lend itself to good sealing kinematics. Some complexity can be expected at the external disconnect area due to the butterfly support system. This unit is recommended as a first choice design candidate.

3.1.2 Split Butterfly. The split butterfly closure consists of two butterfly closure leaves mounted on the centerline of the duct. The leaves are mounted without clearance between them on a split shaft. At separation, the support shaft and the closures part at mating plane. Actuation is by rotation of the split shaft.

The split butterfly closure is exceptional for low spillage upon separation. The unit, however, has outstanding complexities in the support shaft area, in addition to disadvantages listed above for the twin butterfly. Weight penalties can also be expected. This principle is not recommended.

3.1.3 Twin Ball. The twin ball closure makes use of a conventional ball with a large port. Closure is obtained by rotating the ball 90° in its housing so the port in the ball is blocked by the housing. A ball is used on each side of the separation plane so each portion of the duct is sealed after separation.

This type of unit is not recommended due to extreme weight penalties, actuator complexities, large envelope and the need for several external static seals due to the housing separation planes required for assembly. Considerable spillage is inherent for this design.

3.1.4 Unsymmetrical Poppet. The unsymmetrical poppet closure makes use of two poppet valves, one each side of the separation line. The large valve has a suitable seat of such size that the head of the smaller valve can pass through the seat of the larger. The large valve is closed by a spring. The smaller valve is of such length that it is open after installation and in turn opens the larger valve. Booster-tank separation is used to trigger staging. Both halves of the duct are closed during and after separation.

Good sealing kinematics, symmetry of parts, minimum spillage upon disconnection, centerline actuation and adaptability to vent, stage, and fill and drain applications are offered by this unit. Considerable over-all length, however, is required to accommodate the poppets and the related supports and activation devices. It is felt that the unit can be designed for universal use within the 33-inch length limitation. The principle does not lend itself to commonality of parts since the poppets are actuated in the same direction. This unit is recommended as the third design candidate.

3.1.5 Symmetrical Poppet. The symmetrical poppet valve consists of two poppets with the heads of the valves facing each other. The valve seats, the valve heads and a portion of the housing near the separation plane are symmetrical as the name implies. An actuator between the valves is used to open them. The space between the valves in the closed position is small. Both ducts are closed after separation.

Adaptability to common parts is the prime advantage of this system. Actuator complexities, bad flow path conditions, the need for one additional external housing seal, and spillage when disconnected are the disadvantages. The latter two could possibly be eliminated by incorporating an internal pneumatic actuator in the poppets. This, however, could affect commonality of parts and promote closure complexities. This configuration is recommended as a second choice candidate.

3.1.6 Outside Moving Duct Type. The outside moving duct type closure uses two poppet valves arranged head to head with little or no clearance between them. A forward housing and an aft housing is attached at the separation plane which is between the heads of the two valves. There are two bellows which are located at the ends of the housing assemblies. Both closures are actuated by housing motion. The valves seal the ends of the ducts before the start of disconnect and after separation.

This configuration offers simplified poppet design, good flow path conditions and common seals. The prime disadvantages are the long over-all length, the sensitivity of the moving duct to flow dynamics, the lack of adaptability to staging, venting, and fill and drain applications without excessive complexities. This design is not recommended.

3.1.7 Twin Flapper. The twin flapper valve consists of two flappers or leaves with a minimum of space between the leaves. The leaves are supported by a shaft which is also used for actuation. This type valve is symmetrical except for the mechanism used for actuation. At separation, both ends of the duct are closed.

Large unsymmetrical housings, weight penalties, actuating complexities, and problems associated with closure stability in the open position makes this configuration undesirable.

3.1.8 Twin Blade. The twin blade closure consists of two leaf blades for closure. Valve opening occurs when the leaves are retracted into the housings provided. Individual actuators are used. The arrangement is symmetrical except for actuator mechanism. The distance between blades is quite large. After separation, the ends of the duct are closed.

The blade or gate type valve is inherently heavy and bulky due to the storage area required to house the closures in the open position. Adaptability to universal use would not be possible without complexities. This unit is, therefore, not recommended.

3.1.9 Plug Type. The plug type valve is symmetrical, except for possibly the actuating mechanism. There are two valves in the arrangement, one on each side of the separation line. The valve is a tapered plug which seats tightly to shut off flow. A bellows is used to prevent leaks, and also serves as an actuator.

Undesirable flow path conditions, bulky housings, a weight penalty, and no ready adaptability to universal use are the typical disadvantages with this unit. The prime advantage is good seating kinematics. This configuration is not recommended.

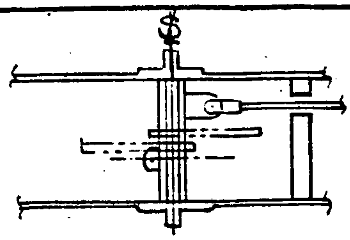
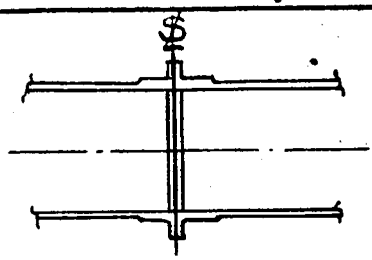
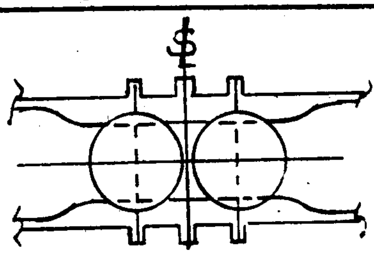
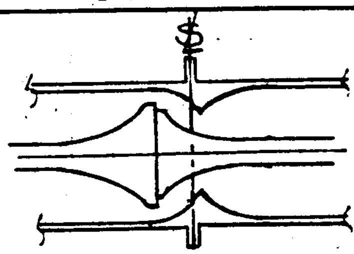
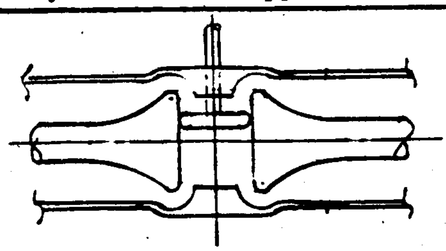
		Fluorine Compatibility	Vehicle Compatibility	Reliability	Test	Preferred Design
3.1.1	 Twin Butterfly	G	E	E	G	First Choice
3.1.2	 Split Butterfly	G	E	P	G	
3.1.3	 Twin Ball	P	P	P	G	
3.1.4	 Unsymmetrical Poppet	G	F	E	G	Third Choice
3.1.5	 Symmetrical Poppet	G	G	E	G	Second Choice

FIGURE 3.1
FLOW AREA AND CLOSURE

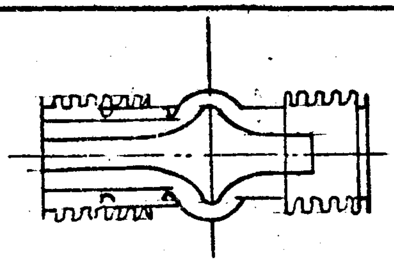
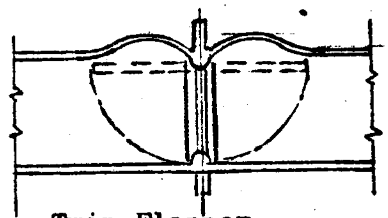
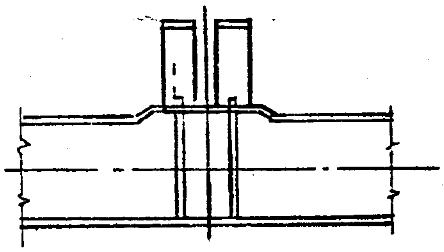
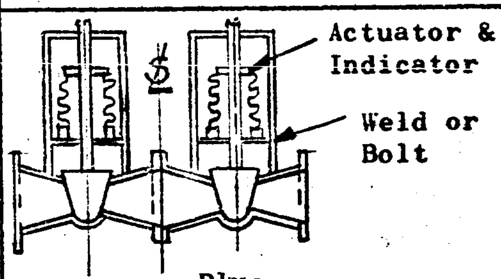
		Fluorine Compatibility	Vehicle Compatibility	Reliability	Test	Preferred Design
3.1.6	 Outside Moving Duct	E	P	G	G	
3.1.7	 Twin Flapper	G	P	G	G	
3.1.8	 Blade	P	P	P	G	
3.1.9	 Plug	G	P	F	G	

FIGURE 3.1 Continued
FLOW AREA AND CLOSURE

3.2 Disconnect Method

The disconnect design shall be capable of universal usage in fill and drain, booster separation and the venting area. Fill and drain and booster separation areas have the capability of providing the disconnect actuator motion. The venting area must be furnished with a separation system for activation of the disconnect. The following are evaluations of various disconnect designs that have been considered.

3.2.1 Explosion Bolts. This concept consists of two flanges held together by explosive bolts. Internal to the bolts are small explosive charges. When this charge is detonated the bolts are torn in two and the flanges part.

Explosion bolts are an electro-mechanical design approach to the disconnect problem. The booster separation system electronics can be used for actuating the disconnect. A separate detonator system circuit can be arranged for the fill and drain, and vent disconnects.

The configuration can use any of those seals evaluated under the heading of static seals.

3.2.2 Ball Detent. This concept consists of two flanges held together by conventional bolts. Steel balls in holes around the periphery of a loose flange forces the loose flange against the static mating member; thereby sealing the connection. An outer ring holds the balls in place until separation is desired. Upon separation, the outer ring is pulled backwards, releasing the balls which are automatically ejected from the holes and the flanges separate.

The ball detent does not lend itself well to the positive release. Very accurate machining of the ball seats is required. This design has doubtful reliability, along with the high cost of very close tolerance machining. Any one of the six evaluated static seals can be used with this application.

3.2.3 Swing Bolts. This concept consists of two flanges and a static seal held together by swing bolts. The swing bolts have spherical washer seats and heads that are wedge shaped. The angled face of the bolt head fits against an angled flange face. Opposite the angled face of the bolt is a small roller bearing. A release collar bears against the bearings and the bolts can then be tightened to fix the static seal. When separation is desired, the release collar is moved back. This action allows the bolts to swing outward and thereby causes the flanges to separate.

The swing bolt disconnect design lends itself to positive disconnection. The release collar can be actuated by booster staging and vehicle lift-off with relatively simple mechanical linkage. An umbilical cord can be used for release in the vent application.

Any of the six evaluated types of static seals can be used with this disconnect design.

3.2.4 Split Vee Band. This concept consists of two angled flanges held together by the wedging action of a split Vee collar. The collar is held together by explosive bolts. When the explosive bolts are actuated, the collar parts disengage and the flanges separate. The collar could also be released by mechanical means.

This configuration lends itself to compact design and simplicity. Seal types such as the conoseal and bobbin could be used due to the low axial load requirements.

3.2.5 Seal Band - Pneumatically Actuated. This concept consists of a thin steel strip placed around two mating flanges and welded in place. A flexible steel strip with attached cutter blades is fastened around the middle of the steel strip. When separation is desired, the cutters are actuated by a hollow metal tube that is pneumatically inflated. The tube is backed up rigidly by a ring type framework, held in place by a steel tension band. Inflation of the tube presses the cutter against the steel sealing strip and thereby causes separation.

The seal band design has an electron beam welded seal strip in place of a static, compression type seal. This method offers a positive seal but complicates the separation operation.

The design is complicated by the need for a tension band, tension band housing, an expansion metal tube and a ring cutter for cutting the welded seal strip, when disconnection is required. The design is adaptable to fill and drain, staging and vent operation, but a pneumatic subsystem is a requirement for actuation. This design would require considerable development time.

3.2.6 Seal Band - Mechanically Actuated. This concept consists of two flanges held together by a thin steel strip. The steel strip is used to both hold the flanges together and to seal the joint. Actuating rods with attached cutter blades are placed around the periphery of the steel strip and the movement of the actuator rods is used to push the cutter blades against the steel strip at separation.

This seal band design has an electron beam welded seal strip in place of a static compression type seal. It provides a positive seal but presents separation problems. The separation is accomplished by sliding rods and attached cutter blades that cut the sealing strip when the rods are actuated. The rods can be actuated pneumatically, hydraulically or by a lanyard.

This design is complicated by the need for slide rods, rod supports and cutter blades. Considerable development will be required to assure high reliability.

3.2.7 Locking Fingers. This concept consists of housing faces, held together by locking fingers. A rearward movement of an outer driver sleeve spreads the locking fingers. When both halves of the coupling are aligned and mated, a forward movement of the outer driver sleeve closes the locking fingers around the mating half of the coupling.

This design concept has been built and successfully tested for small units. A complete report on the experimental evaluation made of this quick disconnect is given in NASA Technical Note D-1727.

3.2.8 Shear Rivets. This concept consists of a plain conoseal wedged in a cavity between two assembled flanges. Soft rivets are used to hold the assembly together during handling or for overcoming loads which may separate the flanges prior to disconnecting. For the interstage and fill and drain applications, the flanges are held in the mated position by the combination of end structural restraints and the internal pressure acting upon the annulus area of the bellows section of the mating ducting.

This configuration approaches the limit for simplicity, when used in fill and drain, and staging areas. The separation force is provided by the vehicle lift-off and booster staging. In the venting area, a separate system must be used to supply the separation force and to simulate the structural restraints provided in the interstage and fill and drain applications.

The reliability of sealing is doubtful since there is no positive attachment between flanges.

3.2.9 Expanding Gas - Shear Break. This concept consists of two flanges, electron beam welded together. One of the flanges incorporates a weakened section designed to fail in shear when expanding gases react on its outer periphery. The second flange has a gas expansion chamber, electron beam welded to the outer diameter.

When separation of the joint is desired, a low power charge is ignited in the gas expansion chamber. The expanding gas fails the weakened section and separation is accomplished.

This concept is a positive zero leakage design but inspection and contamination control of the cavity at the shear section is difficult. The design is adaptable for the fill and drain, booster separation and boil-off vent areas.

Qualification and acceptance testing is somewhat of a problem because the disconnect joint can only be used once.

3.2.10 Shaped Charge. This design consists of a minimum flange arrangement held together by a welded steel band. The band acts as the positive seal to prevent any leakage. When separation is desired, a shaped charge located around the band circumference is ignited failing the band. This design has few parts, is easy to manufacture and assemble, and is adaptable to usage in fill and drain, staging, and boil-off vent area. Development time would be required to insure proper utilization of the shaped charge. Problems may develop in contamination control.

3.2.11 Tension Bolts. This design incorporates two flanges held together by bolts designed to fail in tension. At separation, a load is applied to the bolts by means of a cam or wedge type system which fails the bolts in tension. This system has been used successfully on small valves. However, for the diameters required in these applications, the number of bolts and the mechanism required for loading can become bulky and complex.

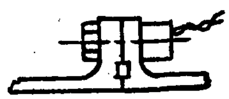
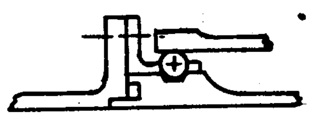
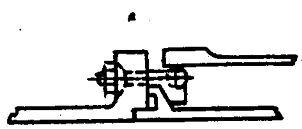
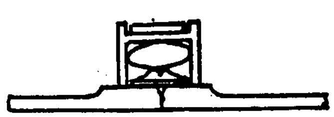
		Fluorine Compatibility	Vehicle Compatibility	Reliability	Test	Preferred Design
3.2.1	 Explosion Bolts	E	E	G	G	Second Choice
3.2.2	 Ball Detent	E	F	P	G	
3.2.3	 Swing Bolts	E	G	G	G	Third Choice
3.2.4	 Split "V" Band	E	E	G	G	First Choice
3.2.5	 Seal Band Pneu. Actuated	P	P	F	P	

Figure 3.2 Disconnect Method

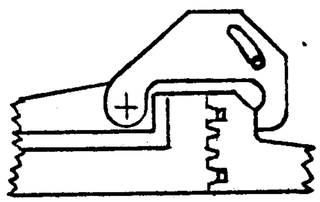
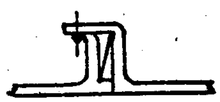
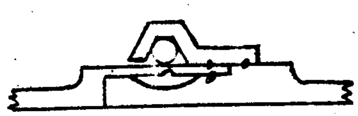
		Fluorine Compatibility	Vehicle Compatibility	Reliability	Test	Preferred Design
3.2.6	 Seal Band Mech. Actuated	F	F	F	P	
3.2.7	 Locking Fingers	E	F	G	G	
3.2.8	 Shear Rivets	E	G	F	F	
3.2.9	 Expanding Gas Shear Break	F	P	F	F	
3.2.10	 Shaped Charge	F	G	F	F	

Figure 3.2 (contd) Disconnect Method

3.3 Actuator

Several combinations of components can be used for an actuator. As an example, different types of actuators may be used, the position of the actuator may vary, the number of bellows and the type may vary, the bellows themselves may be used principally as a flexible ducting or may also be used as an actuator. Figure 3.3 shows the principal actuator arrangements considered and provides a tabulated summary.

3.3.1 Actuator Mounted Aft. In this arrangement, the actuator is mounted on the fill and drain line stub-up. The actuator is an internally mounted pneumatic or mechanical type. Two sets of bellows are mounted in series above the actuator. The bellows provide for axial and lateral motions and misalignments between the vehicle and the ground stub-up. A reducer fitting is attached to the bellows and mates with the airborne valve at the separation line. The fitting incorporates a position indicator for the airborne closure, guides for an internal push rod from the actuator and provisions for completing disconnect assembly when mated with the airborne interface. The primary disadvantage of this design is the influence of vehicle motion upon valve closure position.

3.3.2 Actuator Mounted Forward. In this design a pneumatic or mechanical actuator is mounted inside the reducer fitting which attaches to the airborne interface at the separation line. The valve position indicator is also mounted in this fitting. Two flexible bellows sections are mounted below the housing and provide for the necessary axial and lateral motions.

This arrangement divorces the effects of vehicle motion upon valve closure position. There is no push rod in the bellows area. The bellows lengths can be held to a minimum since the movements and misalignments between vehicle and ground interfaces are the only influencing factors. Airborne closure activation is done only by the internally mounted actuator. This arrangement is recommended as a design candidate.

3.3.3 Externally Mounted Actuator System. This arrangement incorporates a reducer fitting which is attached to the airborne interface at the separation line. This fitting contains the position indicator, an internal push rod guide and external mounting lugs for the actuators. There are two bellows sections below the housing. The straight section between the two bellows assemblies contains a support spider for the closure actuating push rod. Actuation is accomplished by applying load to the straight section causing deflection of the bellows assembly. The aft bellows section accommodates vehicle motions and the axial movement required to actuate the closure. The forward bellows accommodates the closure movements only. Designs are possible where the forward and aft bellows could work as separate units. Long bellows can be realized from this arrangement since both vehicle movements and closure actuation are influencing factors. The design, however, offers outstanding features such as a clean flow path, independence between vehicle motion and closure actuation, and lends itself easily to a highly reliable leak proof actuating system. This arrangement is recommended as a design candidate.

3.3.4 Pressurized Annulus Compartment. The forward position of the assembly is a reducer fitting attached to the vehicle at the separation line. The housing incorporates disconnecting provisions, and the position indicator. An annulus type bellows assembly attaches to the aft side of the housing and to the forward side of an internal spider. A second annulus bellows assembly attaches to aft side of the spider and the ground side of the fill and drain line. The annulus area of the forward bellows assembly is pressurized for actuating the valve to the closed position and the aft bellows assembly is pressurized to open the valve. These operating forces are transmitted from the spider to the valve by an internal actuating probe. Axial and lateral motion is permitted by the two bellows assemblies.

The principal advantage of this design is the simplicity. The chief disadvantages are influences of vehicle motion upon valve closure positions and long bellows sections. This arrangement is recommended as a design candidate.

3.3.5 Externally Mounted Actuator System - Alternate. The principle of this configuration is the same as that described in paragraph 3.3.3, except that it could be more adaptable to a butterfly type valve.

Since the butterfly valve principle relies upon one butterfly actuating a mating butterfly, two identical valve units are used. The valve on the ground side is equipped with position indicators and acts as part of the actuation system. This system is recommended as a candidate.

3.3.6 External Actuators. Several methods can be used for activating the external actuator systems described in 3.3.3 and 3.3.5, such as hydraulic, pneumatic or electromechanical. These in turn can be employed in numerous ways such as in combination with yokes, load cages, flexible shafts with screw jacks, etc.

One arrangement for reducing the number of actuators is shown in Figure 3.3.6a. This method employs a support bracket hinged with a yoke member. One actuator moves the yoke which in turn moves the flex duct

Although high reliability could be realized with this method, the overall kinematics is not favorable.

Figure 3.3.6b shows a design employing screw type jack actuators powered by a central electric drive unit through flexible drive shafts. This arrangement offers high reliability since only one motor assembly is used. A similar method can be employed using three separate screw jack type actuators.

Pneumatic systems offer the advantage of being insensitive to low temperatures. Special thermal isolation features would not be required. The system, however, could become a problem in obtaining a balance load condition. Cylinders with unequal diameters, orificed lines, special mechanical linkages, or combinations of these to obtain a uniform actuation platform could result. Mechanical actuators on the other hand inherently have many parts such as motors, gear boxes, drive screws, slip clutches, etc. These may prove sensitive to the temperatures expected. They offer the outstanding advantage, however, of providing a stable actuation platform.

A hydraulic system would require special temperature isolation features. Since considerable trade-offs must be made which in turn would be closely related to detail designs of a depth beyond the scope of this activity, no final system selection has been made. From current estimates, however, the final selection would probably exclude hydraulic.

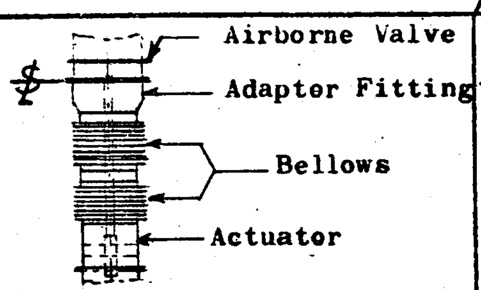
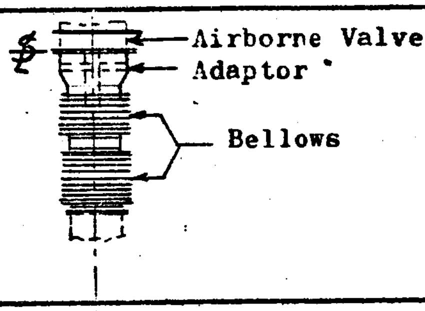
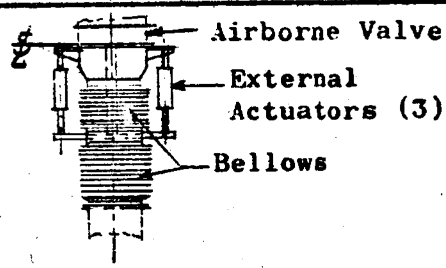
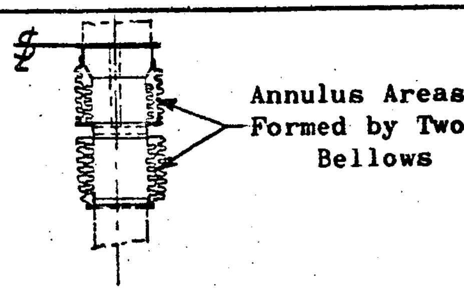
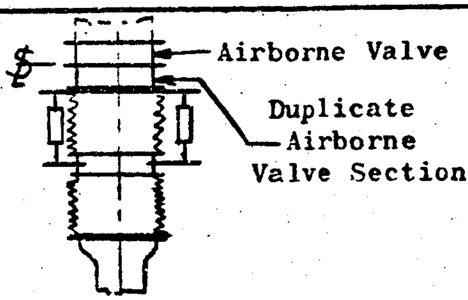
		Fluorine Compatibility	Vehicle Compatibility	Reliability	Test	Preferred Design
3.3.1		F	P	P	G	
3.3.2		F	G	G	G	Second Choice
3.3.3		E	F	G	G	First Choice
3.3.4		G	P	G	G	
3.3.5		E	F	G	G	First Choice for Butter-fly Type Valve

Figure 3.3 ACTUATORS

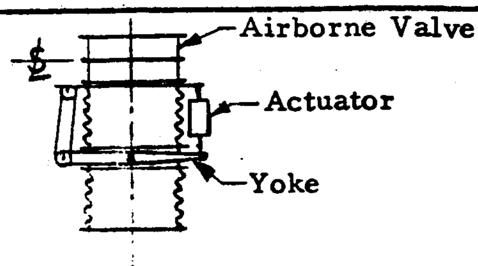
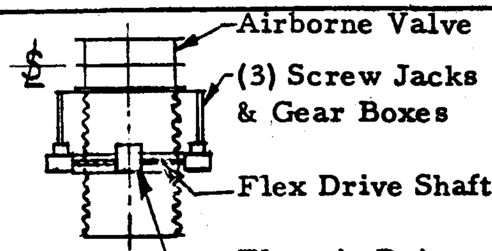
		Fluorine Compatibility	Vehicle Compatibility	Reliability	Test	Preferred Design
3.3.6.a		E	P	G	G	
3.3.6.b		E	F	F	G	

Figure 3.3 (cont'd) ACTUATORS

3.4 Closure Position Indicator

The principal purpose of the closure indicator is to produce a signal or signals proving the valve position. The designs considered are all based on establishing the true position of the closure element and producing a signal only when the fully open or fully closed position is achieved. The principles shown can be employed in pairs to indicate the open and the closed positions. The latter is recommended.

3.4.1 Mechanical Position Indicator. In this design, movement of a probe in contact with the poppet actuates a rod. The actuator rod contacts a micro limit switch which produces the signal. The motion is transferred at right angles by beveled surfaces on the probe and actuator. The mechanism is sealed by a bellows housing the probe and a spring is used to assure contact between probe and closure.

The principal advantage of this type of indicator is that a simple subsystem can be used to produce a signal. The ratio of vertical push rod motion to the limit switch push rod is approximately one to one. Disadvantages exist, however, due to the number of parts in the flow stream and the possible need for purging to assure free operation of the internal mechanisms. This arrangement is recommended as a design candidate.

3.4.2 Pneumatic Position Indicator. In this arrangement, a bellows chamber in contact with the valve closure is used to establish the valve position. A limit switch is actuated by a change in pneumatic pressures. A follower spring is used to keep the chamber in contact with the valve.

The principal shortcomings of this design are sensitivity to temperature changes and small changes in pressure may be insufficient to trigger a pneumatic limit switch with sufficient accuracy.

3.4.3 Electrical Position Indicator. The electrical position indicator is actuated by a magnetic slug attached to the valve closure. As the slug approaches a sensing coil in a probe, a signal is generated. The signal is then amplified and used for a "go" or "no-go" signal.

Mechanically, this design is simple and clean. It has been used on cryogenic fill and drain valves. Its reliability, however, has not been impressive due to electrical complexities in the amplifier. This arrangement is recommended as the first choice design candidate.

3.4.4 Mechanical Position Indicator. The wiggle type position indicator consists of a probe attached to a thin walled tube. The tube has supports which cause a small beam in the tube to bend. The bending causes beam movements at the point where the beam emerges from the housing. A limit switch is actuated by these movements.

The principal merit of this design is the few moving parts and the ease of sealing. A possible need for purging the internal passage to assure smooth operation could be a disadvantage. This arrangement is recommended as a design candidate.

3.4.5 Beam Position Indicator The beam type indicator is a mechanical system that is enclosed in a bellows. A push rod actuated by the closure in turn actuates a beam. The beam is supported on a fulcrum near one end so the motion applied at the short end of the balance beam is amplified approximately 15 times at the opposite end where an adjustable microswitch is actuated.

The principal merits of this system is that movement at the closure is greatly amplified at the microswitch and therefore is quite sensitive. The mechanism is fairly complex since a bellows, stops and adjustmenst must be incorporated in the design. The disadvantages pointed out under 3.4.1 and 3.4.4 would be applicable to this configuration. This arrangement is recommended as a design candidate.

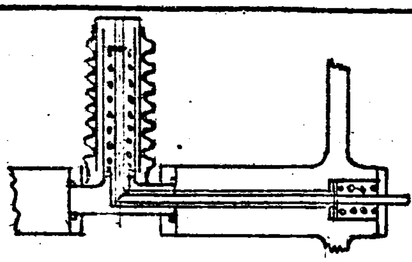
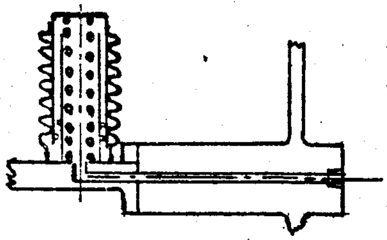
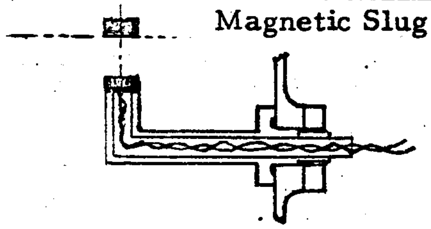
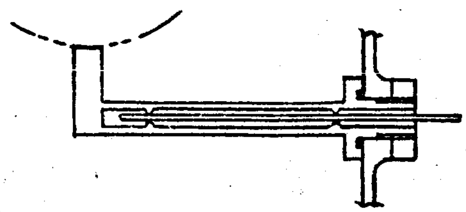
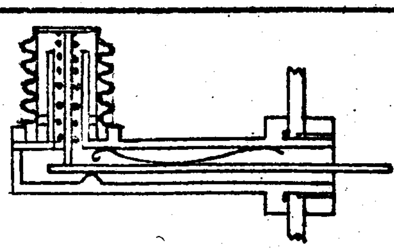
		Fluorine Compatibility	Vehicle Compatibility	Reliability	Test	Preferred Design
3.4.1	 MECHANICAL SYSTEM	G	G	G	G	**Second** Choice
3.4.2	 PNEUMATIC SYSTEM	G	G	P	G	
3.4.3	 ELECTRICAL	G	G	E	G	First Choice
3.4.4	 MECHANICAL	G	F	G	G	**Third** Choice
3.4.5	 MECHANICAL	G	G	G	G	**Second Choice**

Figure 3.4 POSITION INDICATOR

3.5 Flexible Ducting

Provisions for longitudinal and lateral flexibility in any direction must accompany each installation for the staging and fill and drain applications. No provisions are required for the vent installations since flexible ducting is provided from the ground side to the valve assembly. The following designs were considered (see Figure 3.5).

3.5.1 Slip and Omega Joint Combination (Figure 3.5.1). This design uses the slip joint for longitudinal motions and the combined use of the slip and omega joints for the lateral deflections. The slip joint incorporates a dynamic seal assembly capable of allowing longitudinal motion and small angular movements in any direction. The omega joint incorporates an internal gimbal ring assembly capable of angular deflections while restraining in the longitudinal directions. Two omega type joints could be used in series for this concept to relieve angular motions on the dynamic seal assembly in event this should become a problem.

This design offers simplicity since the use of anti-squirm and limit devices are not required. The major disadvantage, however, lies in the slip joint which requires a dynamic seal. The design also contributes complications in isolating the effects of longitudinal motions upon the valve closure positions, especially in the fill and drain application which requires a ± 1.0 inch movement. This design is not recommended.

3.5.2 Two Bellows Sections (Figure 3.5.2). This design employs two bellows sections for accommodating the longitudinal and lateral motions. Externally mounted rods limit the bellows travel within the design limits. This could also be accomplished by using a single internally mounted rod. The former is recommended, however, in the interest of clean flow path conditions. Anti-squirm shields can be added for applications requiring long bellows.

This principle offers good external sealing capabilities and is adaptable to staging and fill and drain applications. In the case of fill and drain, longer bellows sections would be required to accommodate the vehicle longitudinal movements.

Disadvantages are the need for limiting and anti-squirm devices. This configuration is recommended as a design candidate.

3.5.3 Omega Joints and Bellows (Figure 3.5.3). This configuration employs two omega type flex joints (using internal gimbal devices) for accommodating lateral motions and a bellows section for absorbing

3.5.3 (Continued)

longitudinal motions. The bellows section may be placed between or outside the flex joint assemblies depending upon the application. Limit and anti-squirm devices can be externally applied to the bellows section if required.

The configuration offers good external sealing capabilities and can be adapted to the staging and fill and drain applications. In the case of fill and drain, longer bellows would be required to accommodate vehicle longitudinal movements. The need for restraining components for the flex joints and anti-squirm and limiting devices for the bellows section are the disadvantages. The assembly could also prove bulky in the staging application. The omega flex joints offer blind areas which could prove difficult for cleaning and inspection procedures.

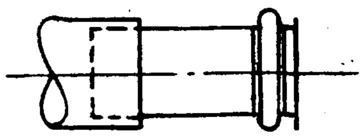
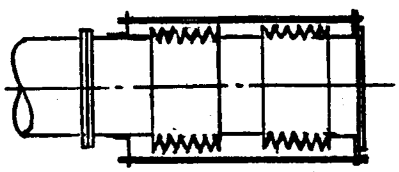
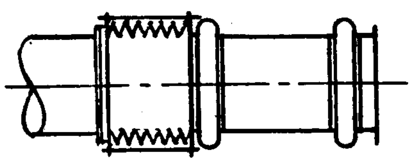
		Fluorine Compatibility	Vehicle Compatibility	Reliability	Test	Preferred Design
3.5.1	 Slip and Omega Joint	P	G	P	G	
3.5.2	 Two Bellows Sections	E	G	G	G	First Choice
3.5.3	 Omega Joint and Bellows	G	F	G	G	

FIGURE 3.5
FLEXIBLE DUCTING

3.6 Disconnect Seals - Static and Dynamic

Zero external leakage is a prime requirement. Two general types of seals, static and dynamic, are presented in the following paragraphs and evaluated in Figure 3.6. The static type seal is more adaptable to zero leakage requirements than the dynamic type seal.

3.6.1 Metal "O" Ring. This static seal arrangement consists of two mating flanges incorporating a finely finished "V" groove in each flange. A hollow metal "O" ring is compressed between the two flanges. High axial flange loads are a requirement, as well as surface perfection in the sealing "V" grooves. This design, however, has proven sealing capabilities in many cryogenic applications.

3.6.2 Naflex Seal. This static seal design consists of two mating flanges with rectangular grooves for housing a Naflex type seal. The seal has two legs that are formed slightly outward. When the seal is in the rectangular grooves the mating surfaces contact the sharp edges of the two legs. Internal pressure tends to force the legs against the sealing surfaces. Considerable axial loads are required. Flange weights can be high since the seal is sensitive to deflections.

3.6.3 Metal Bobbin Seal. This static seal consists of two mating flanges, both of which incorporate a rectangular groove on their mating surfaces. A two-legged metal bobbin fits the inside diameter of the two grooves. The two legs of the bobbin are angled such that when the flanges are mated, the legs are deflected. This deflection causes a wedge type action forcing the ends of the legs against the cylindrical surface of the groove and placing the solid ring section of the seal in tension. Since the solid ring section on the seal must be large to resist the high radial forces, this design yields bulky flanges. The design can be modified, however, by reducing the ring size and allowing this ring to bear on the outside diameter of the flange groove, therefore reducing the flange size. Good contamination control is possible with this design. The configuration is also adaptable to mirror image flanges.

3.6.4 Metal Conoseal. This static seal consists of two mating flanges that compress a metal sealing ring in a cavity formed by the mating surfaces. The wedge type action of the seal causes high radial sealing forces on the grooves. Like the bobbin type, this design uses low axial forces to produce high radial sealing stresses. It contributes to lower disconnect release loads and efficient use of flange material. However, it is not easily adapted to mirror image flange design and contamination control.

3.6.6 Mating Knife Edge Seals. This static seal method consists of two flanges, one of which incorporates a soft metal seal in a rectangular groove. The mating flange incorporates a knife sealing edge that is pressed into the soft metal to obtain a seal. This type does not lend itself to easy replacement. Small axial loads would affect a seal. The design is not compatible with commonality of parts.

3.6.7 Metal Skin Seal. This seal is accomplished simply by electron beam welding a metal skin across the mating members. This metal skin then forms a positive zero leakage joint. Separation can be accomplished by shaped charge or by mechanical cutting devices. Poor contamination control and testing difficulties are part of this design.

3.6.8 Annealed Copper "O" Ring. This static seal concept consists of two flanges, both of which incorporate a rectangular sharp-edged groove, and an annealed copper "O" Ring. The "O" ring is compressed between the two flanges. Considerable axial loads are required to make a seal. The actual seating is accomplished by the double action of the sharp edges of the rectangular grooves forming into the copper ring. Testing results on a 12-inch flange with this type of seal, using gas and liquid nitrogen, are recorded in a General Electric report (NAS8-4012) on design criteria for zero leakage connectors for launch vehicles. Heavy flanges can be expected from this design.

3.6.9 Lip Type Seal. This dynamic seal consists of a flange arrangement to hold the dynamic seal blade, as well as a static metal seal. The flange also holds a seal retainer that is designed to act as the initial guide for the sliding mating valve housing. This design requires many parts. A great deal of development would be required with no assurance that zero leakage could be realized.

3.6.10 Hollow Ring Seal. This dynamic seal concept consists of two concentric flange sections and a hollow metal seal ring brazed to the inside of the outer flange. The metal seal ring has a local raised section on its inner diameter. This raised area is required to slide on the smooth outer diameter of the inner flange.

This design would require a good deal of development to obtain minimum leakage.

3.6.11 "V" Ring Seal. This dynamic seal uses an outer flange that holds a "V" ring seal. One leg of the "V" seal is used to seal on the inner face of the outer flange, and the second leg of the "V" seal is a close sliding fit on the inner member. Fluid pressure on the leg of the "V" seal would tend to improve the sealing action. High development could be expected.

3.6.12 Spring Ring Seal. This dynamic seal concept consists of two concentric cylindrical sections with a spring ring welded onto the inner periphery of the outer cylinder. The contact of the spring ring on the smooth outer surface of the inner flange is expected to accomplish the sealing. Fluid pressure under the spring ring can be used to aid the sealing. Zero leakage would be difficult with this design.

3.6.13 Spring Seal with External Loading. This dynamic seal consists of outer and inner concentric members with the outer member incorporating a welded spring seal. The spring seal maintains spring contact with the inner member. A tension band is used around the spring seal to make it possible to adjust the sealing load. High development can be expected.

3.6.14 Beam Welded Strip - Tearing Action. This concept consists of two mating members with a single, thin steel, tear sleeve welded between them. Local raised areas around the body of the inner sleeve are added in short radial lengths to insure tearing of the thin sleeve when separation is desired.

This concept has a unique feature which allows axial movement before the tearing action begins. Questionable contamination control and difficulty with qualification and acceptance testing are part of this design.

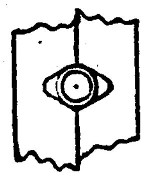
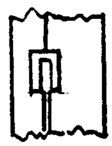
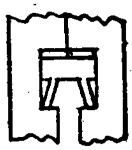
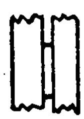
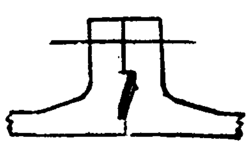
		Fluorine Compatibility	Vehicle Compatibility	Reliability	Test	Preferred Design
3.6.1	 Metal "O" Ring	G	G	G	G	Third Choice
3.6.2	 Pressure Side Naflex	G	P	F	G	
3.6.3	 Metal Bobbin	E	E	F	G	First Choice
3.6.4	 Lead Clad Copper Flat	G	F	F	G	Fourth Choice
3.6.5	 Metal Conoseal	G	E	G	G	Second Choice

FIGURE 3.6
DISCONNECT SEALS

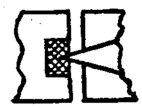
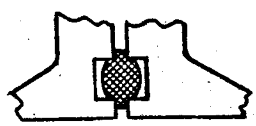
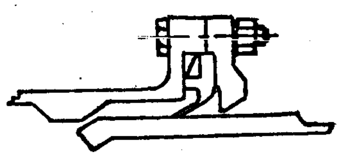
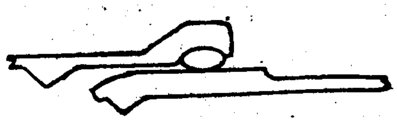
		Fluorine Compatibility	Vehicle Compatibility	Reliability	Test	Preferred Design
3.6.6	 Mating Knife Edge	F	P	P	G	
3.6.7	 Metal Skin	F	E	F	F	Fifth Choice
3.6.8	 Annealed Copper "O" Ring	F	F	F	G	
3.6.9	 Lip Type	P	F	P	G	
3.6.10	 Hollow Ring	P	F	P	G	

FIGURE 3.6 Continued
DISCONNECT SEALS

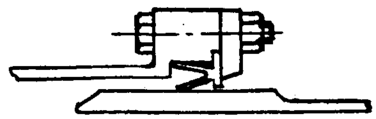
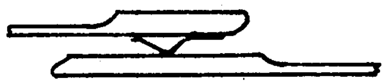
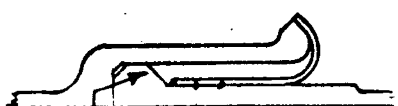
		Fluorine Compatibility	Vehicle Compatibility	Reliability	Test	Preferred Design
3.6.11	 "V" Ring	P	F	P	G	
3.6.12	 Spring Ring	P	F	P	G	
3.6.13	 Spring Seal With External Loading	P	F	P	G	
3.6.14	 Local Raised Edges for Tearing Beam Welded Strip Tearing Action	P	P	F	F	

FIGURE 3.6 Continued
DISCONNECT SEALS

3.7 Closure Seals

The mating of two seals face to face or diameter to diameter is the basic sealing mode. Combinations of these, together with various materials, are used. Some of the seal arrangements shown in Figure 3.7 are more suitable for poppet type closures, while others are more suitable for the butterfly type. Some could be adapted to either type of closure. Various arrangements are evaluated in Figure 3.7. Development effort can be expected for any of the selected designs.

3.7.1 Soft Metal Insert. The seal in this design consists of a hard surface bearing on a soft metal. The soft metal region can be a brazed insert or be soft plating.

Hard surfaces on a soft material minimize the effect of deflections and permits greater tolerances and surface imperfections than are permissible with hard mating surfaces. This surface is more appropriate for use in a poppet type closure. When an insert is used, contamination control may be difficult. Sealing repeatability is not good. This design is not recommended for design.

3.7.2 Hard Metal Surfaces. This design uses two hard metal surfaces. A wide land or large contact area is used in conjunction with highly finished surfaces.

This design is best suited for the poppet type closure. Good sealing has been attained with this method on small valves. The method provides good contamination control. Sensitivity to fluid contaminates, surface scratches and deflections are the prime disadvantages. These problems are augmented when a large valve is considered. The deflection problems alone could impose considerable weight penalties. This design is not recommended.

3.7.3 Hard Metal - Narrow Land. This configuration uses a hard metal ridge bearing on a hard flat surface. High sealing stresses are obtained with this method.

Sensitivity to fluid contaminates, surface scratches and deflections can be expected. However, good contamination control is offered. This method is not recommended.

3.7.4 Spring Steel Belt. This design makes use of a spring seal belt in contact with a soft metal region. The spring belt is welded or brazed in place. The soft region can be a brazed insert or be soft plating.

The spring base mated with a soft area minimizes the effects of deflections and permits greater tolerances and surface imperfections. Contamination control may be a problem. This arrangement is recommended for design.

3.7.5 Pressurized Ring for Poppet. In this arrangement, the closure is engaged with a soft metal torus seat ring brazed in the housing. The seat is pressurized with helium after engagement causing high radial seating loads.

Since clearances can be large between the closure and the seal ring prior to seating, the effects of deflections and tolerances are minimized.

An unfavorable feature is the necessity for a subsystem and the resultant decrease in reliability. This arrangement is recommended as a design candidate.

3.7.6 Mechanically Expanded. The mechanically expanded method has a thin wall flat seat area in the closure that is expanded mechanically into the housing seat after the sealing position is reached. The actuating mechanism operates like a conventional internal expanding mechanical brake. To obtain uniform expansion at the periphery, a six or eight shoe design is used.

The principal advantages of this configuration are the same as for the pressurized ring of Figure 3.7.5. The expanding mechanism is complex and contamination control would be difficult. This design is not recommended.

3.7.7 Cono Type. This arrangement makes use of a conventional cono type seal mounted in the closure. A rolled lip on the closure is used to retain the seal. The housing incorporates a mating sealing ledge. Upon engagement, the cono type seal wedges between the two mating surfaces.

The faying surfaces between closure and seal result in poor contamination control. Sealing repeatability would be poor. Alignment may also be a problem since the sealing diameters require close tolerances. This arrangement is not recommended for design.

3.7.8 Non-metallic Soft Seat. This design employs two-stage sealing. A metal to metal seat is used to cut off the bulk flow. A metal ridge on the housing is then mated with soft plastic material on the closure to form the final seal.

Hardware complexities and poor contamination control are inherent in the plastic seal assembly. Compatibility of the plastic seal is also questionable for this type of service. This method is not recommended.

3.7.9 Metal Spring Lip. This arrangement makes use of a spring type seal formed into a "J", "L" or convolute type cross section or combinations of these shapes. The metal spring seal is welded to the closure and engages with a highly finished surface in the housing. The upstream pressure tends to increase the sealing load. This method can be made relatively insensitive to deflections and tolerances.

Some difficulty can be expected in contamination control at the junction between seal and closure and the scraping action between lip and housing in the case of the butterfly application. These features can be overcome, however, by good detail design. This arrangement is recommended as a design candidate.

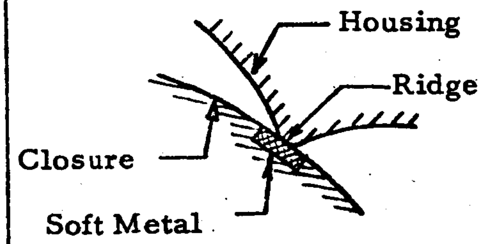
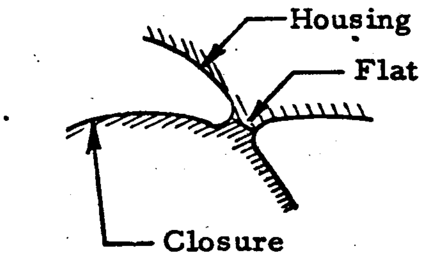
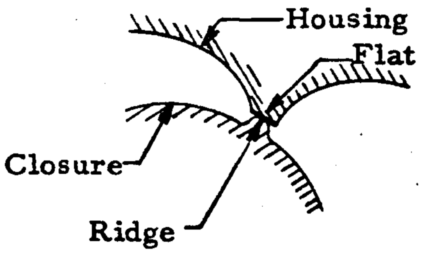
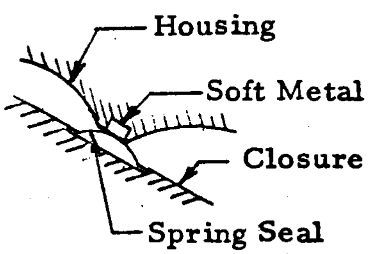
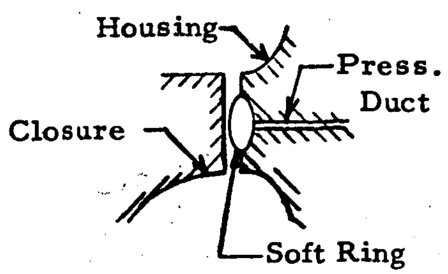
	Diagram	Fluorine Compatibility	Vehicle Compatibility	Reliability	Test	Preferred Design
3.7.1		G	G	F	P	
3.7.2		G	F	P	G	
3.7.3		G	F	P	G	
3.7.4		F	G	F	G	Third Choice
3.7.5		G	F	G	G	Second Choice

Figure 3.7 Closure Seals

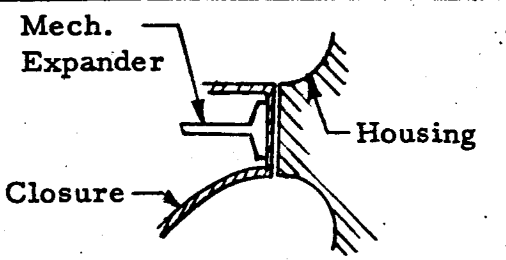
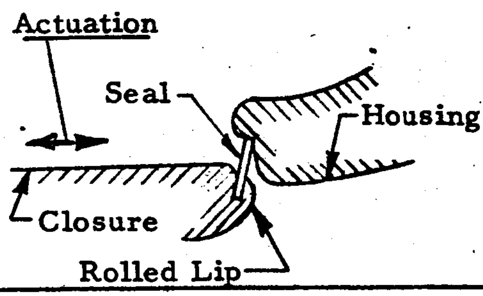
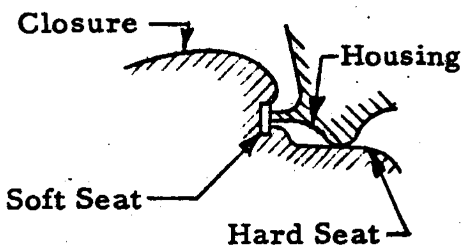
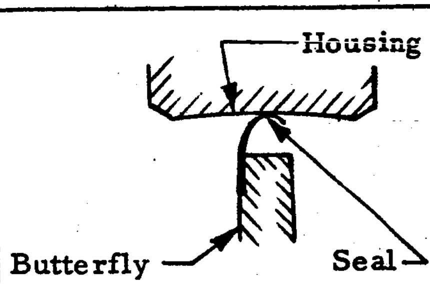
		Fluorine Compatibility	Vehicle Compatibility	Reliability	Test	Preferred Design
3.7.6		F	G	P	G	
3.7.7		P	F	F	G	
3.7.8		P	F	F	G	
3.7.9		G	G	G	G	First Choice

Figure 3.7 (cont) CLOSURE SEALS

4.0 INTEGRATED DISCONNECT DESIGN

General Design Features. The integrated design shown in Figure 4-1 is a size 11-inch configuration incorporating four basic parts; a sustainer fitting, two butterfly closure units and a flexible duct section. The length, diameter and interfaces of the unit permit installation as a staging valve on the present Atlas "D" series vehicles without changes to existing ducting. Commonality of components also permits its use in the fill, drain and vent areas with minor vehicle changes.

For universal usage, the basic parts are interconnected using flanged joints incorporating static metal seals, with the exception of the disconnect area between the two closure units which employ a special disconnect "V" type flange using a static metal seal and release band assembly.

Prime considerations were given to maintaining a clean and simple flow passage. No screw threads, faying surfaces, hidden passages, bushings, special bearings, lubricants, plastics, brazing, or moving shafts piercing flow passage walls were employed. Any accessories required to operate the unit are located externally to the flow path. All welds between the bellows and the mating flanges are electron beam butt welded. The flow area, therefore, incorporates only two integrally machined butterfly closures, one actuating rod, an integrally machined cross type support beam and support pins for the butterflies and actuating rod. The assembly uses K-monel, 718 Inconel, copper and corrosion resistant steel throughout (see Figure 4-1), with the exception of the sustainer fitting which is aluminum for weight savings. The configuration also includes position indicators for positive detection of the fully open and fully closed positions of the butterfly closures. Limit rods, limit sleeves, lanyard devices and a squirm shield are mounted externally as required, depending upon the application. The external lanyard cables are equipped with protective shields for preventing accidental release.

4.1 Flow Area and Closure. The flow area incorporates two butterfly type closures with hinge points offset in two planes (see Figure 4-4). This method places the mating faces parallel in the fully open or fully closed position and allows the upstream pressure to maintain the butterfly in the closed position after disconnecting. The offset pivots improve the sealing kinematics of the closures since, in the open position, the seal is near the centerline of the valve assembly. The relief bore in the housing, therefore, prevents distortion of the seal in the open position. Upon closing, the closure seal is wiped into the mating surface of the housing near the closed position.

4.1 (Continued)

One butterfly is attached to an actuating rod and serves as the driver for the mating butterfly. Actuation is accomplished by the heel or toe area of one unit bearing on an area of the mating unit (see Figures 4-2, 4-3 and 4-4). Each closure incorporates a local raised strip integrally machined with the closure structure to serve as an actuating ramp. No galling or material release is expected between the ramp surfaces since the loads are relatively low and the closure materials selected allow a high degree of hardness.

As the butterflies actuate from the open to the closed position (see Figures 4-2 and 4-3), the volume between the two blades increases until the mid-position is reached. Further closing causes this volume to decrease. The closing rate, however, does not provide sufficient time for fluid to fill the cavity since the sudden initial departure of the blade surfaces can cause a low pressure region with a resultant gas pocket formation. Near the end of the closing cycle, this gas is compressed to the liquid state prior to closure sealing. It therefore appears that the volume between the seals will be a combination of gas and liquid or all gas, therefore providing a compressible media. In event a pressure build-up develops in the trapped volume, the seals will momentarily deflect toward the mainstream sides providing a relief valve effect. This entrapment effect tends to relieve the shock loading conditions assumed in this design. A detail analysis, accompanied with tests, should be included for this area in the prototype development program.

Each butterfly is mounted in a rigid ring type housing containing local external bosses for receiving the butterfly support pins, local internal stop lips and a polished seal zone. The butterfly support pins are assembled from inside and do not pierce the housing wall. These pins and the actuating rod pins are retained by soft rivets. Problems with galling or seizing between support pins and mating parts is not expected since high hardness and hardness differences can be maintained with the materials selected, together with low bearing stresses and limited motions.

The butterfly structure is basically a waffle type incorporating an "H" type beam at the support pin centerlines and cantilever web type beams running 90° to the former. The open side of this structure faces the pressure side for minimum residuals at disconnect. Loads required to actuate the closures are applied directly into the primary webs of this structure. The skin covering the waffle structure is primarily for sealing. The closure assembly including beams, webs, skin, actuating lugs, etc. are integrally machined from a single piece of raw stock. The seal is electron beam welded to the rim portion of the structure.

4.2 Disconnect Area. The ring type housings containing the butterfly closures mate at the separation line with "V" type flanges containing a static seal. These flanges are retained in the mated position by a split "V" type release band capable of sustaining loads expected for any of the three applications. This release band is divided into three sections which are retained as an assembly by three release pins (see View GG, Figure 4-1). Each of these three sections are, in turn, composed of two sections fastened by a hinged joint using an eye bolt. The eye bolts are used for applying tension to the band. The release band, therefore, consists of six segments. Upon withdrawal of the release pins, the three band sections (each section hinged at the mid-point) disengages from the disconnect flanges. Release can be initiated by the withdrawal of any one pin since all other sections are hinged. A leaf type kick spring can easily be spotwelded to the release band if required. The disconnect band components are retained with the booster or ground hardware by catch cables shown in View LL of Figure 4-1. The disconnect seal is retained at the booster or ground flange by three small pins pressed into the flange which, in turn, mate with local grooves in the ring section of the seal.

Special attention was given to the method for retracting the three "V" band release pins. Release rods incorporating shear pin devices and attached to the release pins with short cable sections were considered. The use of rods, however, requires moving the release pins outboard from the position shown in Figure 4-1, due to the lateral and angular tolerances between the mating interface flanges at installation. These tolerances cause interference between the rods and the bellows assembly unless sufficient clearances are provided. Increasing the outboard position causes unfavorable load paths to the support spider and the disconnect band.

The use of rods only (no cable sections) was also considered. This method employed a sleeve type design at the release pin fitting. The rods were allowed to move inside a tubular section incorporated in the release pin assembly. Stops on the rods and tubular sections activate release. This method, however, is not adaptable to clean design since additional features are required to absorb installation misalignments.

The use of cables offered the simplest design since the movements due to misalignments and deflections are absorbed in the flexibility of the cable.

4.3 Actuator Area. The butterfly closures are actuated internally by a single rod fastened to a spider beam which is integral with the flex duct section. Movement of the spider beam, therefore, actuates the closures. Actuation loads are applied externally to the spider beam. In the case of staging applications, vehicle separation movements are used for actuation. For vent and fill and drain applications, external actuators are employed.

4.4 Position Indicator. The ring type housings containing the closures incorporate two local bosses (see View CC and View DD and the inboard view of Figure 4-1) for mounting position indicator probes. Each probe contains a temperature compensating coil and a signal coil. Opposite these probes and located on the butterfly are magnetic slugs. As the magnetic slug approaches the sensing probe, an electrical signal is generated. Approximate spacing between slug and sensor is .020 inch. Signal ceases when spacing exceeds approximately .050 inch.

The magnetic slug is retained in the butterfly closure by rolling or staking the slug into the mating material. In detail design, the slug or the closure mating areas may reflect access grooves or recessed areas for easy inspection and contamination control.

The position indicators are required only for the fill and drain application. These units can also be conviently employed for the vent area. Staging applications require no indicators.

4.5 Flexible Ducting. The flexible ducting assembly consists of two flanges and a support spider assembly interconnected with two bellows sections. The bellows are electron beam butt welded to the mating components. The support spider section consists of a cylindrical shell with two internal cross beams and three external actuating lugs which are used for valve operation (see View AA of Figure 4-1). These lugs, in effect, are extensions of the internal beams so that the loads are passed directly to the internal members. One flange mating with the aft bellows incorporates three support lugs for the lanyard devices.

The assembly also includes a squirm shield which is assembled in three 120^{o} sections. The shield has local cut-outs for clearing the external support lugs. The flex duct assembly is capable of deflections required for closure actuation, and lateral, angular, and axial movements between installation interfaces. The clevis sections of the internal actuating rod are provided with sufficient clearances such that binding will not result when the flex duct section is laterally displaced.

4.6 Disconnect Seals. The valve assembly employs static seals on all external joints. The metal "O" ring seal is used in all joints (except for the disconnect flanges) due to its low cost, availability and proven performance on similar applications. The metal "O" ring has proven effective also for aluminum to steel joints in liquid hydrogen and oxygen services. The disconnect flanges, however, require special considerations due to tolerances and the close relationship between the seal and the disconnect devices. A modified type bobbin seal (see Reference 1) was chosen since this principle requires low axial loads to produce high radial seating loads. The seal also offers easy contamination control and is adaptable to mirror image flange design.

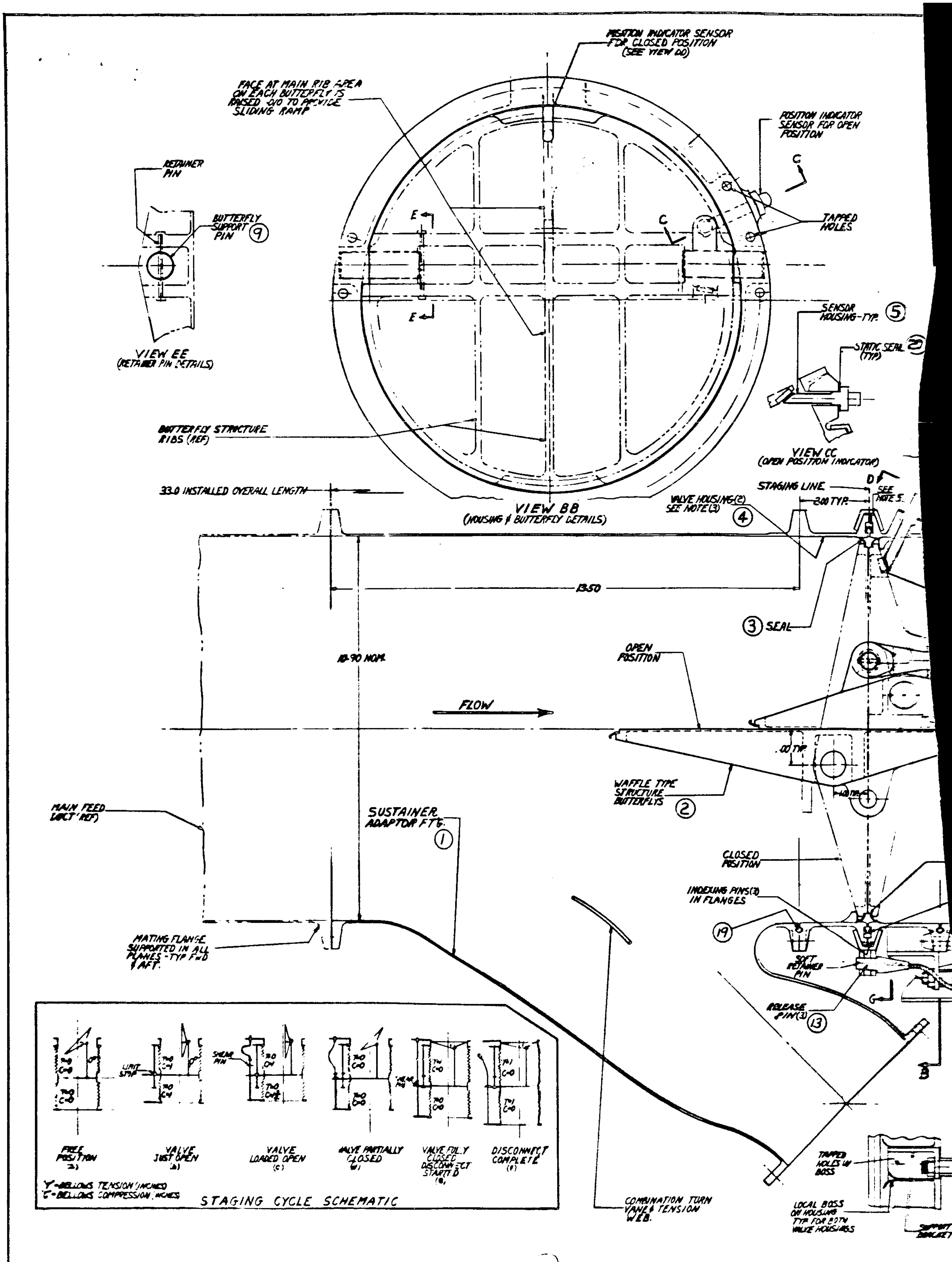
Normally, the bobbin seal incorporates a large ring section for reacting the radial seating loads. This large ring, in turn, requires large disconnect flanges which places unfavorable load conditions upon the disconnect band assembly. It, therefore, appears reasonable to engage the seal ring with the mating flange surfaces for reacting the radial seating loads. This also provides a convenient alignment and retaining element for the two closure housings.

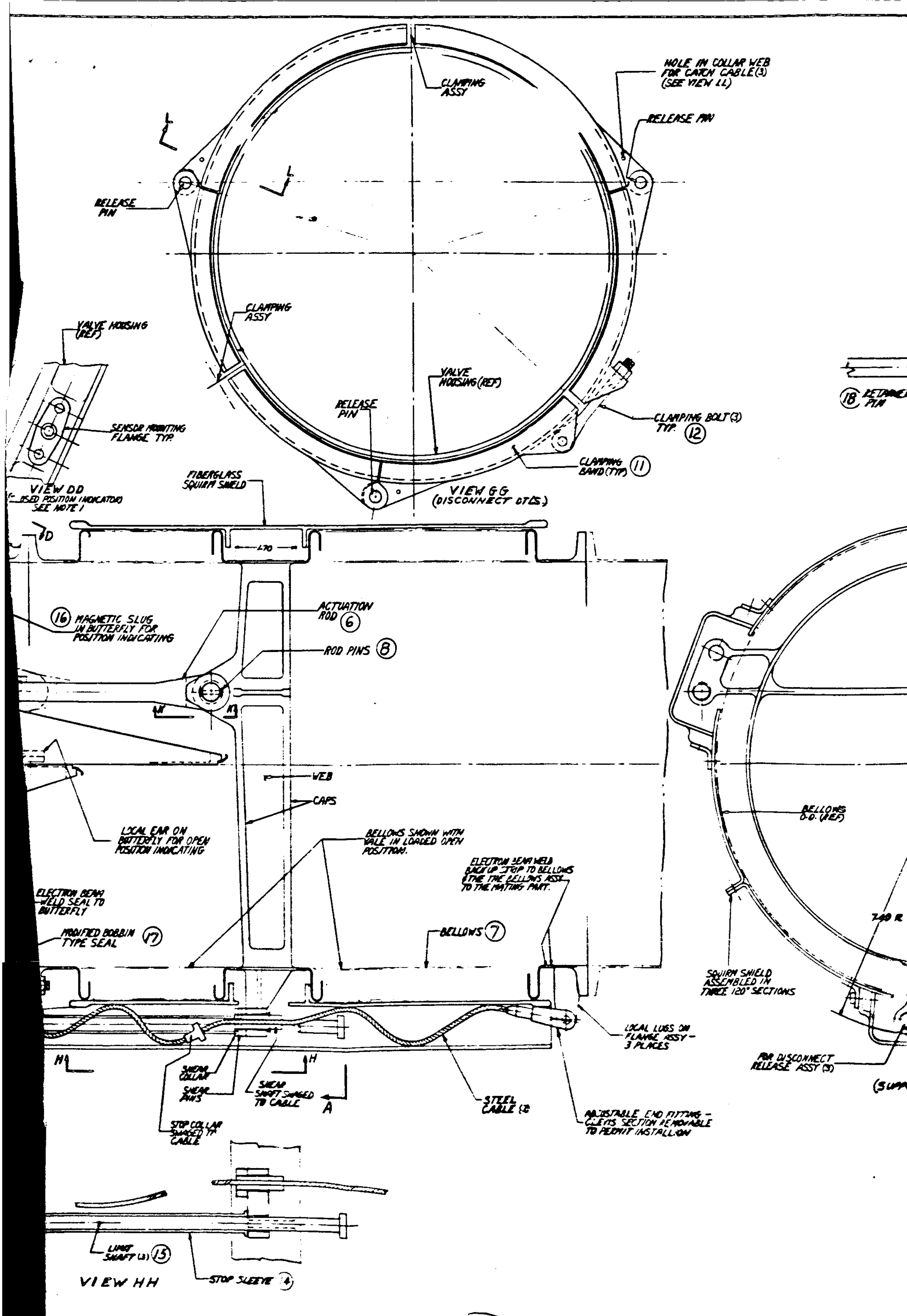
4.7 Closure Seals. The metal to metal dynamic seal between closure and housing is considered a partial development area due to the numerous variables. The configuration shown may not comply with the final design.

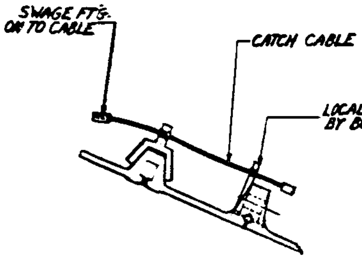
A conservative approach was taken in this area by using a radial seating load of 75 lbs per lineal inch. Actual seating loads, however, may develop to 1/3 or 1/4 of this value. However, in the interest of reliability, the valve structure has been estimated around the 75-lb figure.

The seating surface in the housing is a highly finished narrow land section raised slightly above the main relief bore area. The relief bore area is a loose tolerance area and provides for butterfly seal clearances. The closure seal is electron beam welded to the rim of the butterfly closure. Soft plating may be employed on the seal, depending upon final design analysis.

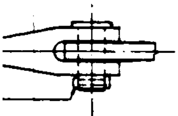
4.8 Materials. The materials listed on Figure 4-1 have been chosen for their compatibility with fluorine, ease of fabrication, availability, ability to maintain high mechanical properties at the temperature ranges expected, and adaptability to rework. The latter could prove valuable in the prototype phase.


POSITION INDICATOR SENSOR FOR CLOSED POSITION (SEE VIEW DD)
FACE AT MAIN RIB AREA ON EACH BUTTERFLY IS RAISED .010 TO PROVIDE SLIDING RAMP
POSITION INDICATOR SENSOR FOR OPEN POSITION
RETAINER PIN
BUTTERFLY SUPPORT PIN 9
TAPPED HOLES
SENSOR HOUSING-TYP. 5
STATIC SEAL (TYP) 20
VIEW EE (RETAINER PIN DETAILS)
BUTTERFLY STRUCTURE RIBS (REF)
VIEW CC (OPEN POSITION INDICATOR)
33.0 INSTALLED OVERALL LENGTH
STAGING LINE
SEE NOTE 5
VIEW BB (HOUSING & BUTTERFLY DETAILS)
VALVE HOUSING(2) SEE NOTE(3) 4
2.00 TYP.
13.50
3 SEAL
OPEN POSITION
18.90 NOM.
FLOW
WAFFLE TYPE STRUCTURE BUTTERFLYS 2
MAIN FEED DUCT (REF)
SUSTAINER ADAPTOR FTG. 1
CLOSED POSITION
INDEXING PINS(3) IN FLANGES
19
SOFT RETAINER PIN
RELEASE PIN(3) 13
MATING FLANGE SUPPORTED IN ALL PLANES - TYP FWD & AFT.
SHEAR PIN
LIMIT STOP
FREE POSITION (a)
VALVE JUST OPEN (b)
VALVE LOADED OPEN (c)
VALVE PARTIALLY CLOSED (d)
VALVE FULLY CLOSED DISCONNECT START (e)
DISCONNECT COMPLETE (f)
Y - BELLOWS TENSION (INCHES)
C - BELLOWS COMPRESSION INCHES
STAGING CYCLE SCHEMATIC
COMBINATION TURN VANE & TENSION WEB.
TAPPED HOLES IN BOSS
LOCAL BOSS ON HOUSING TYP FOR BOTH VALVE HOUSINGS


HOLE IN COLLAR WEB FOR CATCH CABLE (3) (SEE VIEW LL)
CLAMPING ASSY
RELEASE PIN
RELEASE PIN
CLAMPING ASSY
VALVE HOUSING (REF)
SENSOR MOUNTING FLANGE TYP.
VALVE HOUSING (REF)
RELEASE PIN
CLAMPING BOLT (3) TYP. 12
CLAMPING BAND (TYP) 11
VIEW DD
VIEW GG (DISCONNECT DTLS.)
FIBERGLASS SQUIRM SHIELD
.470
16 MAGNETIC SLUG IN BUTTERFLY FOR POSITION INDICATING
ACTUATION ROD 6
ROD PINS 8
WEB
CAPS
LOCAL EAR ON BUTTERFLY FOR OPEN POSITION INDICATING
BELLOWS SHOWN WITH VALVE IN LOADED OPEN POSITION.
ELECTRON BEAM WELD SEAL TO BUTTERFLY
MODIFIED BOBBIN TYPE SEAL 17
BELLOWS 7
BELLOWS O.D. (REF)
SQUIRM SHIELD ASSEMBLED IN THREE 120° SECTIONS
LOCAL LUGS ON FLANGE ASSY - 3 PLACES
FOR DISCONNECT RELEASE ASSY (3)
SHEAR COLLAR
SHEAR PINS
SHEAR SHAFT SWAGED TO CABLE
STEEL CABLE
STOP COLLAR SWAGED TO CABLE
ADJUSTABLE END FITTING - CLEVIS SECTION REMOVABLE TO PERMIT INSTALLATION
LIMIT SHAFT (3) 15
VIEW HH
STOP SLEEVE 4

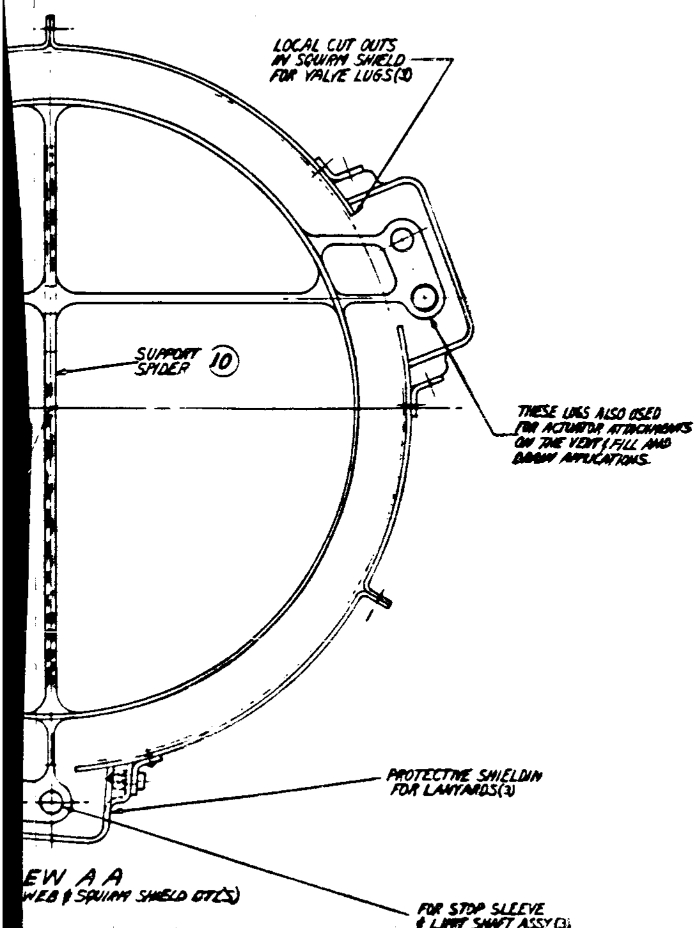


VIEW LL
(ROTATED 90° C.W.)



VIEW KK

ITEM	MATL.
① SUSTAINER ADAPTOR FTG	2219 AL ALY OR 6061 T6
② BUTTERFLY	K MONEL OR 718 INCONEL
③ BUTTERFLY SEAL	BERYLLIUM COPPER (SEE NOTE 2)
④ VALVE HOUSING	K MONEL OR 718 INCONEL (FOREST RING)
⑤ SENSOR HOUSING	321 CRES OR K MONEL
⑥ ACTUATION ROD	K MONEL OR 718 INCONEL
⑦ BELLOWS	718 INCONEL OR K MONEL
⑧ ROD PINS	718 INCONEL OR K MONEL (SEE NOTE 4)
⑨ BUTTERFLY SUPPORT PINS	718 INCONEL OR K MONEL (SEE NOTE 4)
⑩ SUPPORT SPIDER	718 INCONEL OR K MONEL
⑪ CLAMPING BAND	A286 CRES
⑫ CLAMPING BOLTS	A286 CRES
⑬ RELEASE PIN	A286 CRES
⑭ STOP SLEEVE	A286 CRES
⑮ LIMIT SHAFT	A286 CRES
⑯ MAGNETIC SLUG	430, 442 OR 443 CRES
⑰ DISCONNECT SEAL	718 INCONEL
⑱ RETAINER PIN	321 CRES
⑲ SEAL	321 CRES
⑳ SEAL	COPPER (FLAT SEAL) OR A286 CRES K SEAL



EW AA
WEB & SQUIRM SHIELD OTC(3)

5. SPOTWELD LEAF TYPE HIGH SPRING SECTIONS TO "V" BAND IF REQD.
4. GALLING SUPPRESSED BY HEAT TREATING PINS TO HIGHER HARDNESS THAN MATING PARTS.
3. BOTH HOUSINGS INCORPORATE SEVEN LOCAL EXTERNAL BOSSES FOR POSITION INDICATORS, MOUNTING PADS & BUTTERFLY SUPPORT PINS.
2. NICKEL ALLOYS OR NICKEL MAY BE USED DEPENDING UPON DEVELOPMENT. SOFT PLATING CAN ALSO BE EMPLOYED.
1. POSITION INDICATORS USED ONLY ON FILL + DRAIN APPLICATIONS.
NOTES:

INTEGRATED DISCONNECT DESIGN

FIGURE 4-1

3

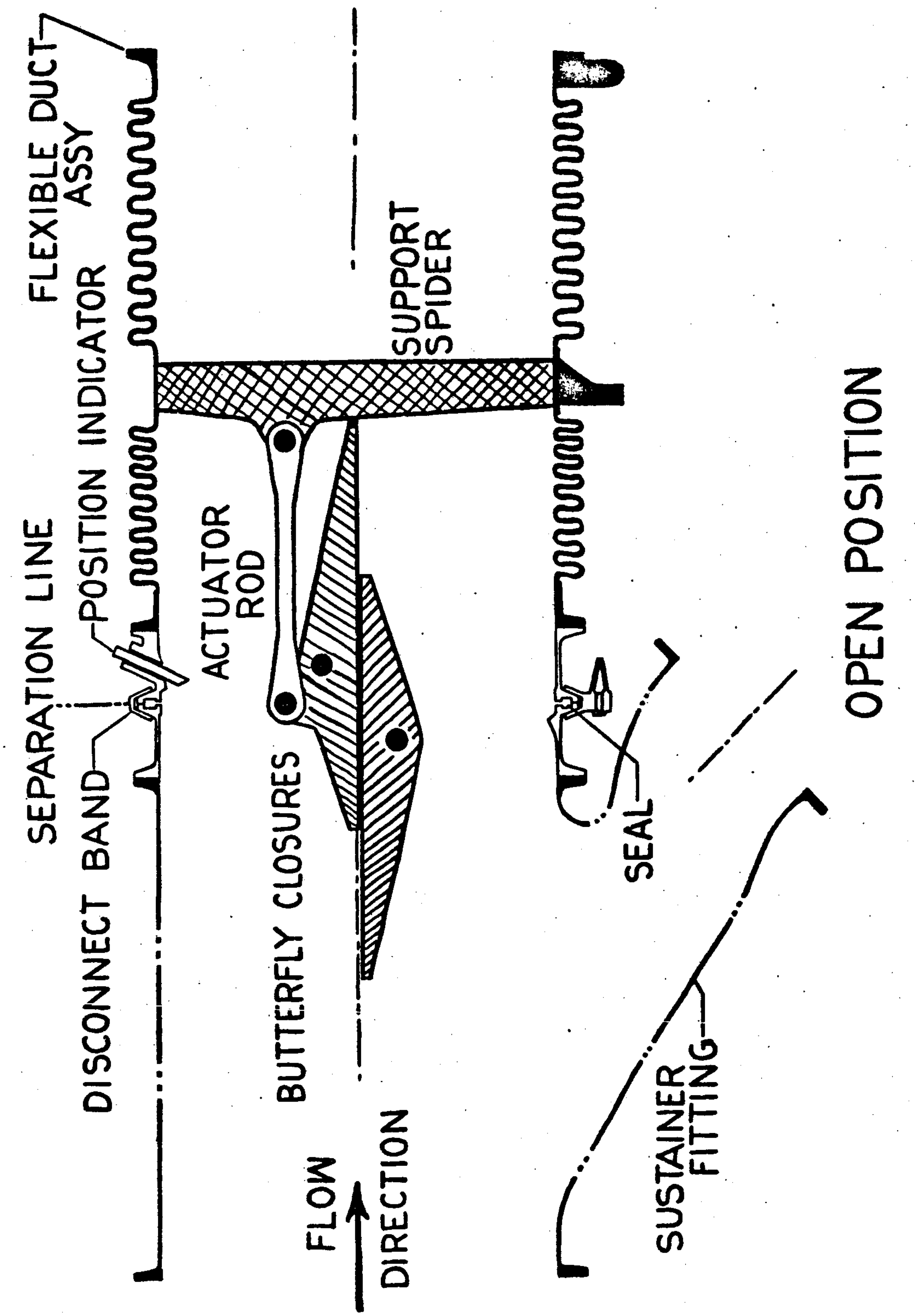
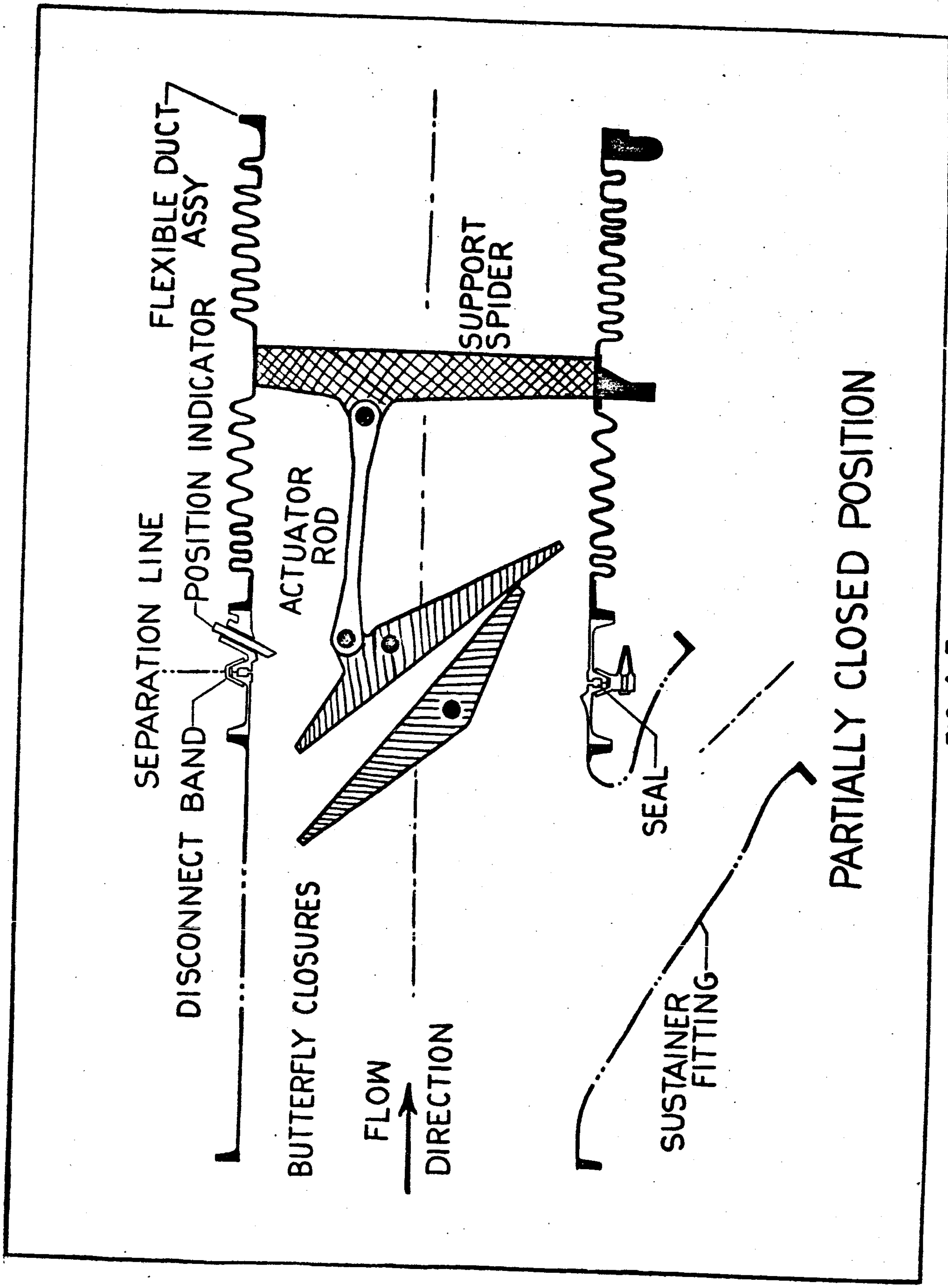
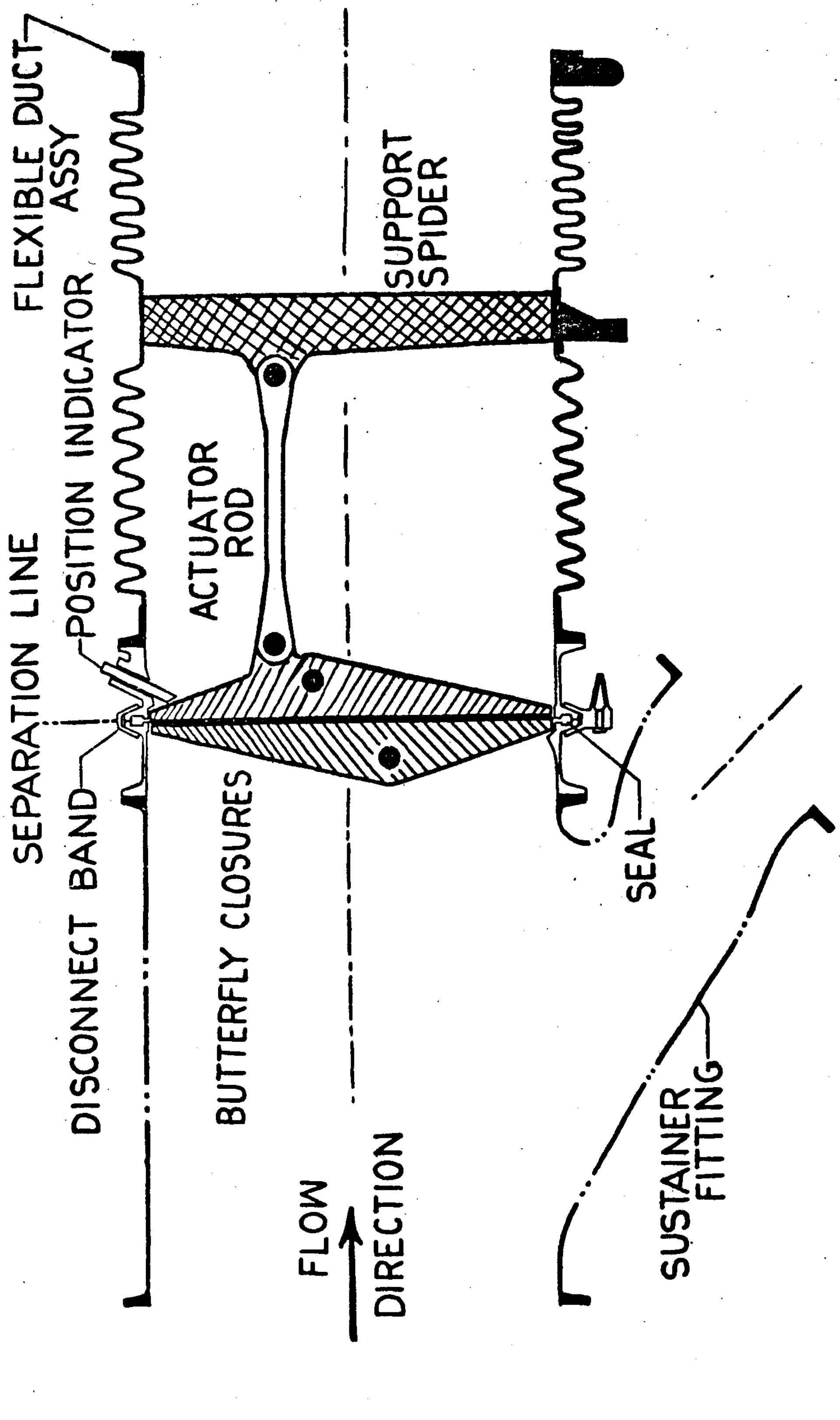

FLEXIBLE DUCT ASSY
POSITION INDICATOR
SUPPORT SPIDER
SEPARATION LINE
POSITION INDICATOR
ACTUATOR ROD
DISCONNECT BAND
BUTTERFLY CLOSURES
SEAL
OPEN POSITION
FLOW DIRECTION
SUSTAINER FITTING

FIG 4-2



PARTIALLY CLOSED POSITION

FIG 4-3



CLOSED POSITION

FIG 4-4

5.0 INSTALLATIONS (GENERAL CONSIDERATIONS)

The 11 inch disconnect valve is designed for use in the interstage, fill and drain, and boil-off functions of Atlas "D" Series vehicles (see Figure 5-4). In the event future developments warrant considerations for two valve sizes, the current systems would permit the use of size 8 inch units for the fill and drain and boil-off applications.

The fill and drain and boil-off installations use both closure elements due to refurbishing advantages. This could change, however, in the vent area, depending upon future developments of the venting modes. The unit, however, is easily adaptable to a single closure installation by simply omitting one butterfly.

5.1 Boil-off Installation. The boil-off installation requires a flexible line leading from the ground boom to the vehicle. Movements between the vehicle and the ground structure is, therefore, absorbed in the flexible line section. This flexible section, however, transmits loads to the disconnect. Since the disconnect valve assembly incorporates a flexible bellows type actuator section, these ground loads must bypass this area and be reacted back to the rigid section of the assembly; namely, the valve housings which, in turn, are supported from the vehicle structure.

A structural tie between the valve housings and the terminating flange of the bellows actuator assembly is also required to react the closure actuating loads..

These load transmissions are accomplished by attaching a reducer fitting equipped with a ring type collar to the bellows section of the standard valve assembly (see Figure 5-1). The opposite end of this reducer fitting is attached to the ground flex line. A cylindrical load cage is installed over the standard valve assembly and one end fastened to the ring section of the reducer fitting and the opposite end attached to the mounting pads on the valve housing. Three linear type actuators are attached to the standard lugs on the valve assembly and to the support ears provided on the load cage. The lanyard release cables are protected by routing inside the load cage. Release is accomplished by a cylinder located on the boom which delivers the required release load to the cables. In event of release cylinder failure, a cable system on the boom provides loads to the valve release lanyards during vehicle motion.

The complete standard valve, including the disconnect joint is bench assembled. This assembly may then be attached to the vehicle ducting and structure, as shown in Figure 5-1. The load cage can be easily

5.1 (Continued)

designed in several ways to allow installation before or after the valve assembly is attached to the vehicle. The ground flex duct section is attached after the load cage installation.

The airborne duct will require the addition of a reducer and a bellows section. Structural provisions would also be required in the vehicle adapter section for mounting the valve. These are considered minor.

5.2 Interstage Installation. The complete standard valve assembly (shown in Figure 4-1), including the sustainer fitting is required for the inter-stage application. No external load cage is required since the forward and aft flanges of the vehicle ducting provide the structural restraints. Actuation of the valve closures and the disconnect is by the vehicle staging motion. No subsystems are required. The over-all installation is shown in Figure 5-2.

The complete unit, excluding the sustainer fitting, is assembled prior to vehicle installation. Referring to the staging cycle schematic shown on Figure 4-1, the following describes the events from installation through complete valve actuation and disconnecting:

a) Prior to installation, the closures are at the 45° position when the bellows sections are in the free length.

b) At installation, the forward and aft bellows sections are compressed one inch with the forward bellows limited by two stops. One of these is the stop sleeve shown in View HH of Figure 4-1. The second stop is the internal butterfly and push rod assembly. The forward bellows section is, therefore, limited to one-inch compression. The valve is now in the open, unloaded position.

c) Axial and lateral movements and misalignments occur between the forward and aft flanges of the vehicle oxidizer duct, due to structural deflections, and manufacturing tolerances. This is compensated for by compressing the aft bellows an additional 3/4 inch (spring rate approximately 800 lbs/inch). This load, therefore, maintains the butterflies in the open position. The valve is now in the loaded open position.

d) Referring to Figure 4-1, the valve is equipped externally with three limit rods and three umbilical cables. Each cable is equipped with a swadged fitting and mating shear collar assembly containing shear

5.2(d) (Continued)

pins. These shear pin assemblies are located approximately at the center of each cable and are assembled in the external lugs of the valve support spider. Each cable also contains a swadged stop collar located 1 to 1-1/4 inches forward of the shear pin assemblies.

Upon vehicle staging, the forward and aft bellows return to the free length position, placing the butterflies in a partially closed position since the support spider in this maneuver travels one inch. At this partially closed position, the aft sections of the cables are placed in tension transmitting loads through the shear pins and into the internal support spider.

e) As vehicle staging proceeds, the three sets of shear pins continue to apply load to the internal support spider until the valve is fully closed. At this moment, the slack in the forward section of the cables is zero and the shear pins fracture due to the structural tie across the valve assembly caused by the limit rods and the internal actuating rod. Referring to the schematic in Figure 4-1, the valve is now in the fully closed position with disconnecting started.

f) Upon failure of the shear pins, the disconnect collar release pins are pulled from their positions by the cables, therefore releasing the "V" band and separating the two valve sections. Following disconnect, the bellows section is axially restrained by the limit rods and the stop collars on the cables. The purpose of the length between the shear pins and the stop collars on the cables is to allow sufficient time for disconnect actuation after valve closing. All disconnect components are retained by small catch cables on the booster side of the assembly.

5.3 Fill and Drain Installation. Figure 5-3 shows the fill and drain installation details. A new airborne "T" fitting is required. This fitting is designed to adapt to the present airborne ducting and provide an 11-inch interface for receiving the standard valve unit. The centerline of the 11-inch interface is located at the maximum outboard position, compatible with vehicle transportation clearances. This outboard position provides clearance between the booster structure and the ground section of the valve assembly. A slight increase in oxidizer residuals can be expected from this fitting compared to the present installations.

The standard valve assembly with external load cage and actuators shown for the boil-off installation is also employed here. Additional heat

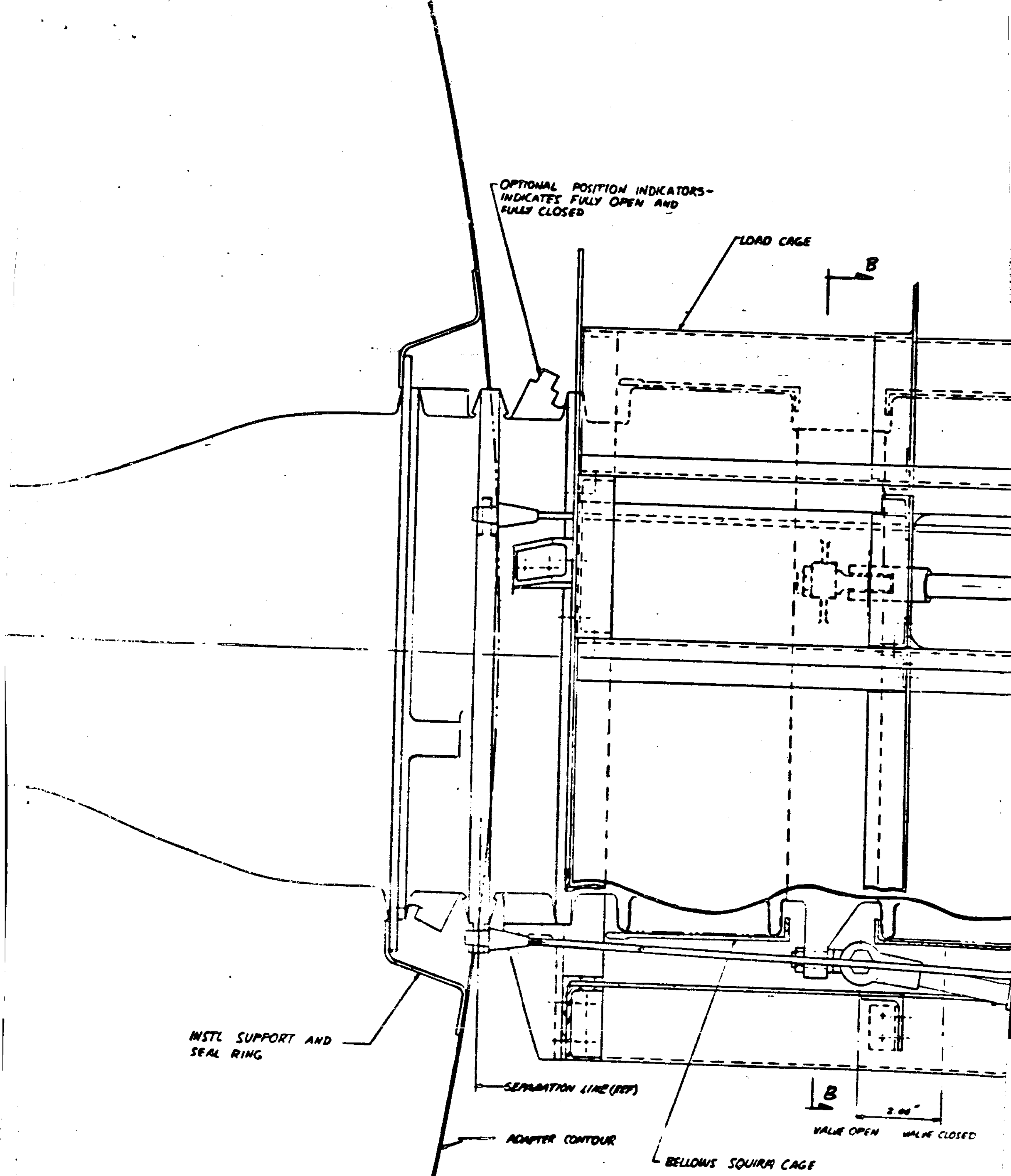
5.3 (Continued)

shielding for the actuators and flex sections are employed as required. These can be easily attached by a variety of methods to the load cage. The standard pre-assembled valve is attached to the vehicle at the 11-inch flanged interface provided by the airborne "T" fitting. The load cage may be attached prior to or after this installation.

A reducer fitting, equipped with a ring type collar, is attached to the bellows section of the valve. This fitting is also used in the boil-off installation. To provide for axial and lateral misalignments and motions between the vehicle and the ground stub up, an aft bellows section is attached between the reducer fitting and the ground interface. Heat shielding attached to the load cage envelops this bellows section. To prevent excessive extension of the aft bellows section at lift-off, limit rods are installed between the load cage and the ground stub up. The lanyard release cables are routed inside the load cage and the heat shielding assemblies for preventing accidental release and protection from the exhaust plume.

The cable ends are attached to lugs on the ground stub up. At vehicle lift-off, the cables pull the disconnect release pins, therefore disengaging the valve separation "V" band. The cables are adjusted with a pre-set slack for preventing release during pre-launch vehicle motions.

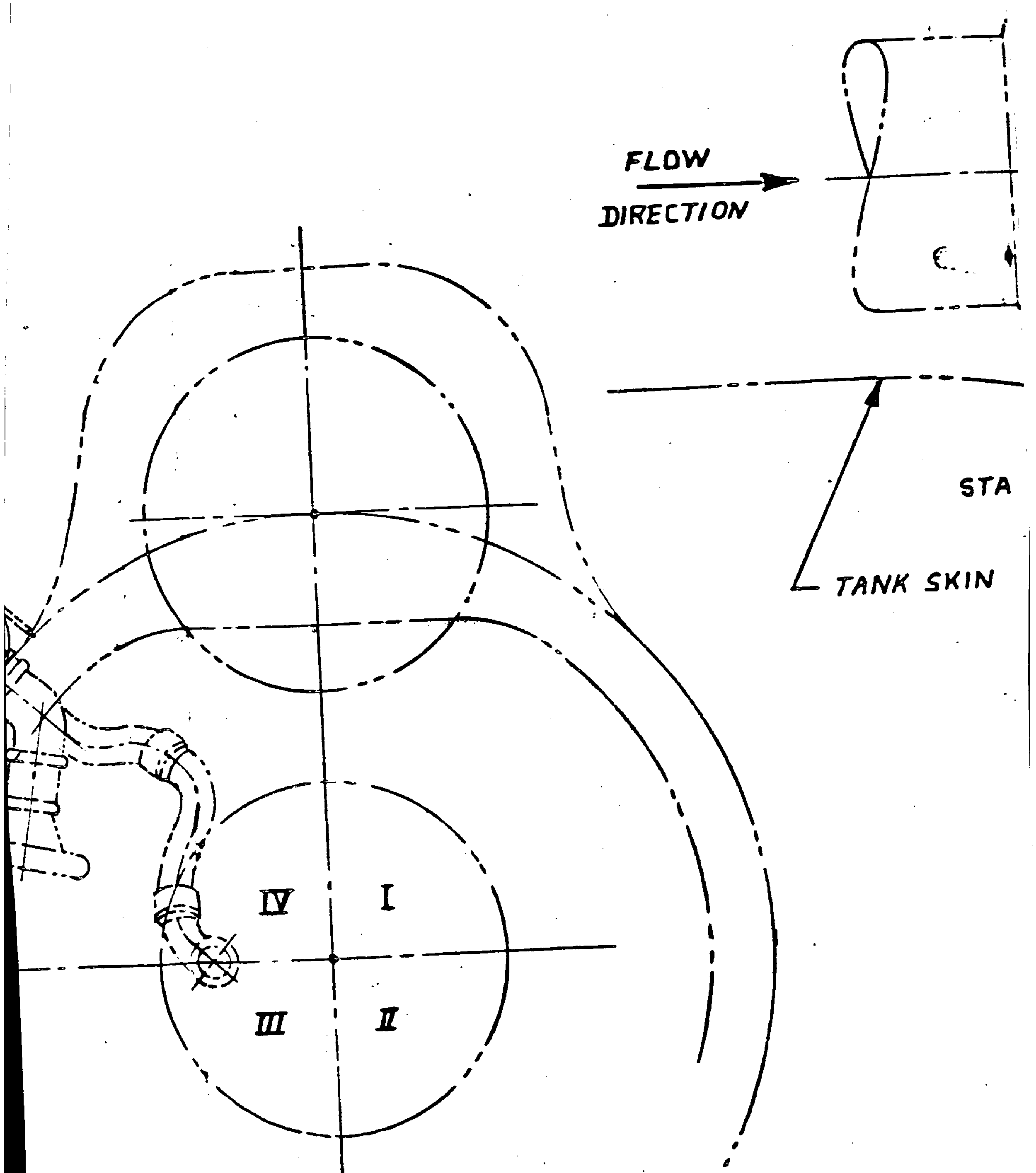
After lift-off, the exhaust plume may laterally deflect the ground assembly sufficiently to damage the aft bellows section. This can be prevented by providing a simple framework from the launcher at the outboard area for limiting lateral deflections. Another method is to incorporate limiting features in the heat shielding assembly.



VIEW A
(FULL SIZE)

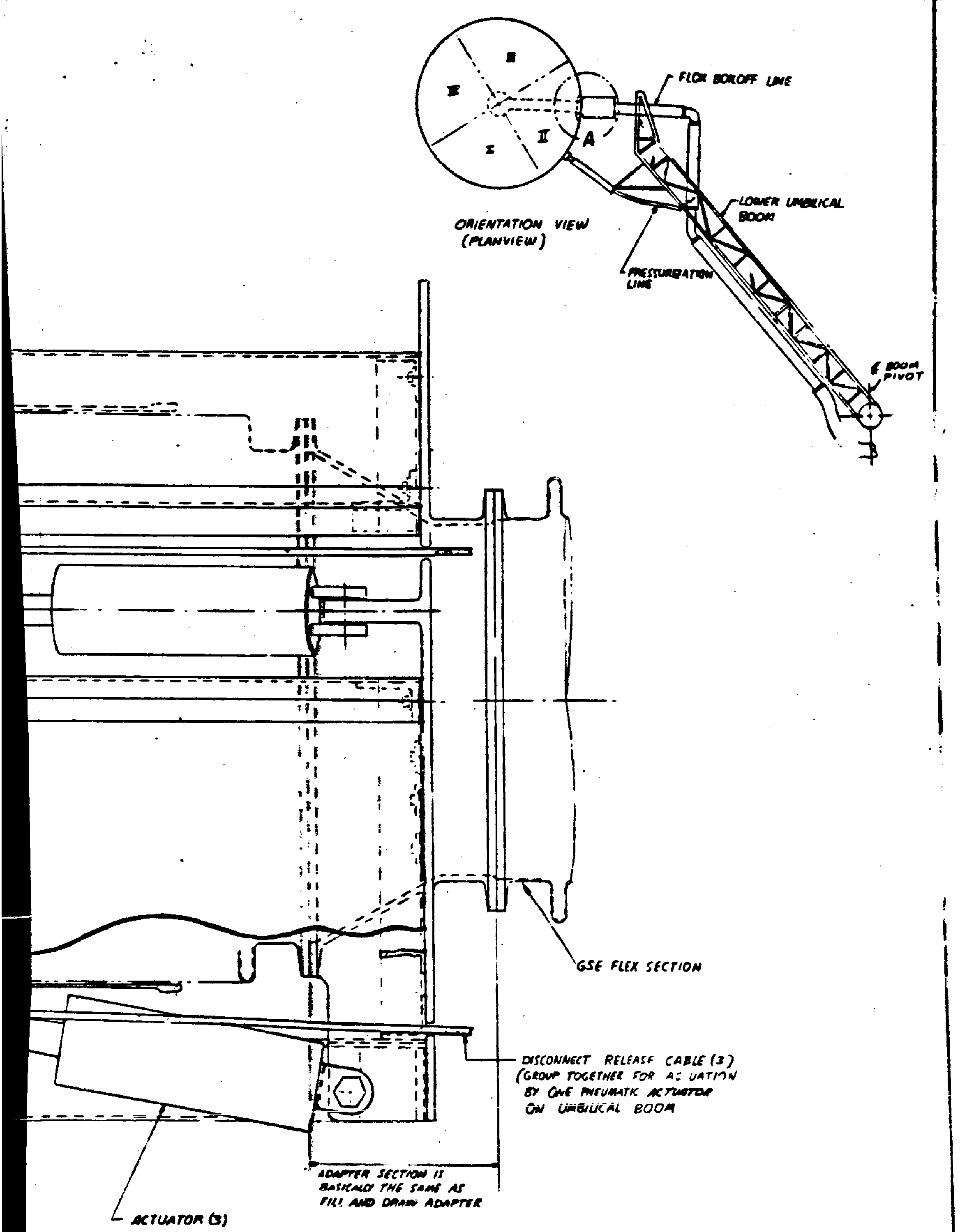
67

2



68 2

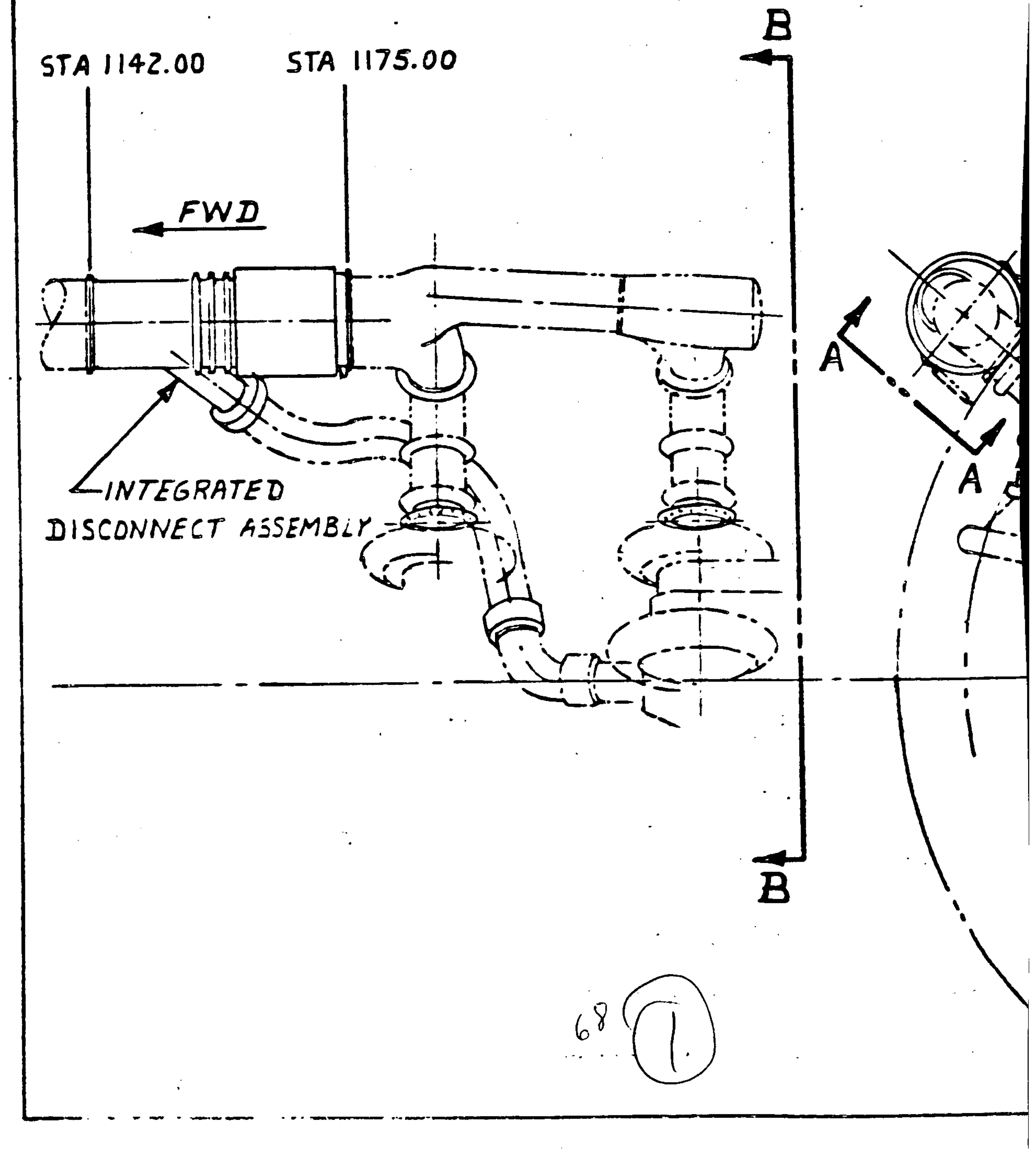
VIEW B-B



67

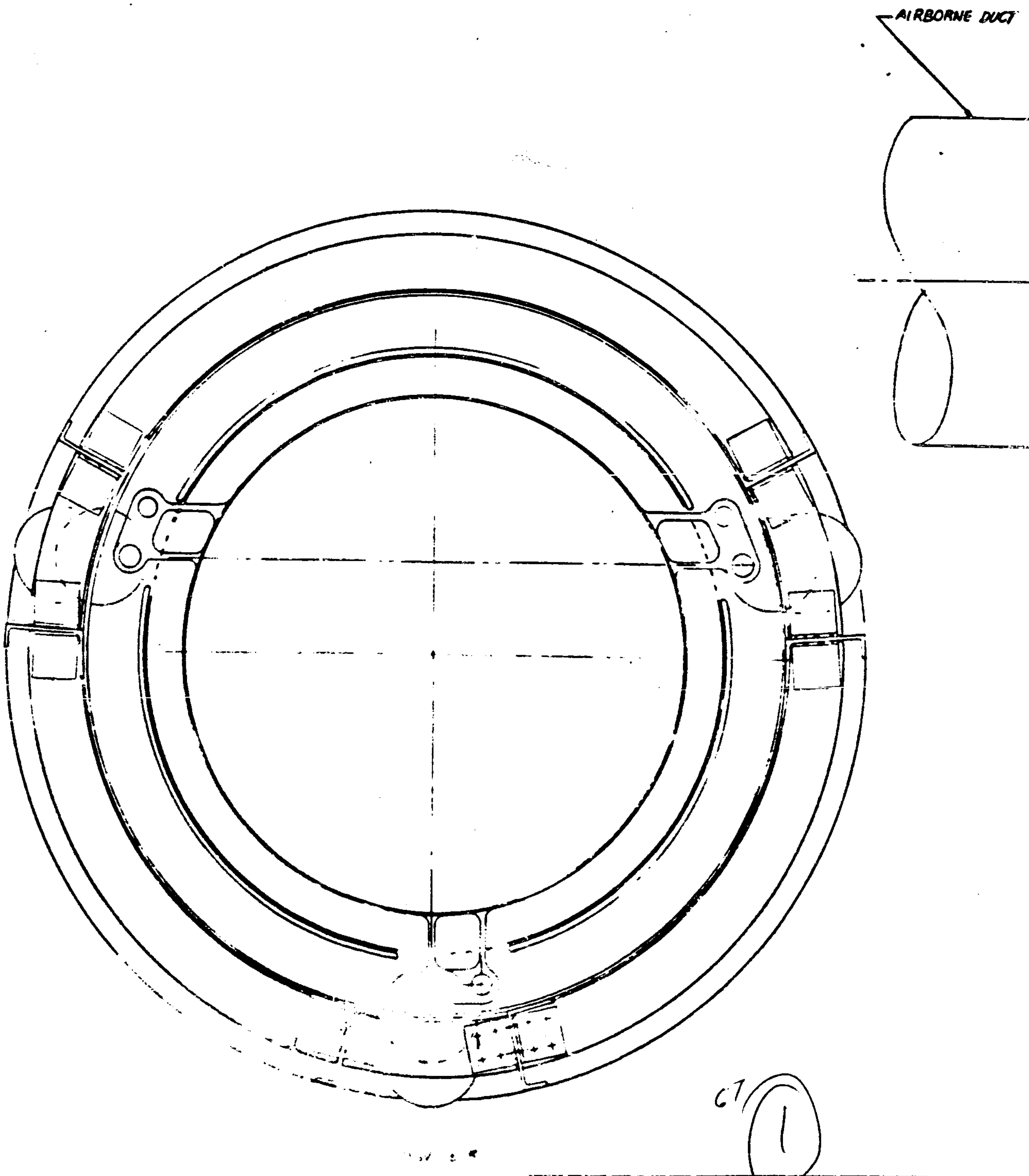
3

BOIL OFF INSTALLATION
FIG 5-1

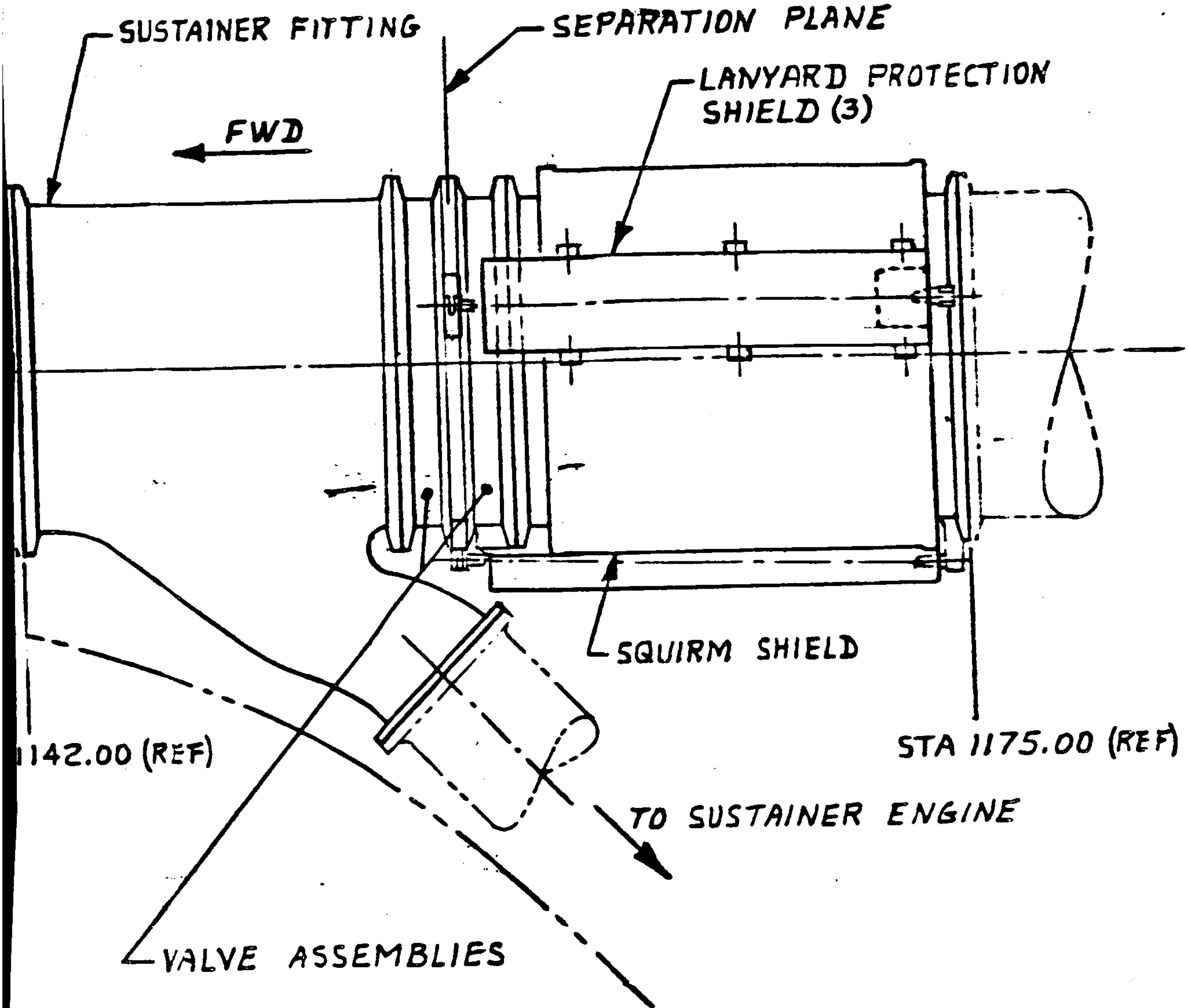


STA 1142.00
STA 1175.00
FWD
B
B
A
A
INTEGRATED
DISCONNECT ASSEMBLY

68 1.



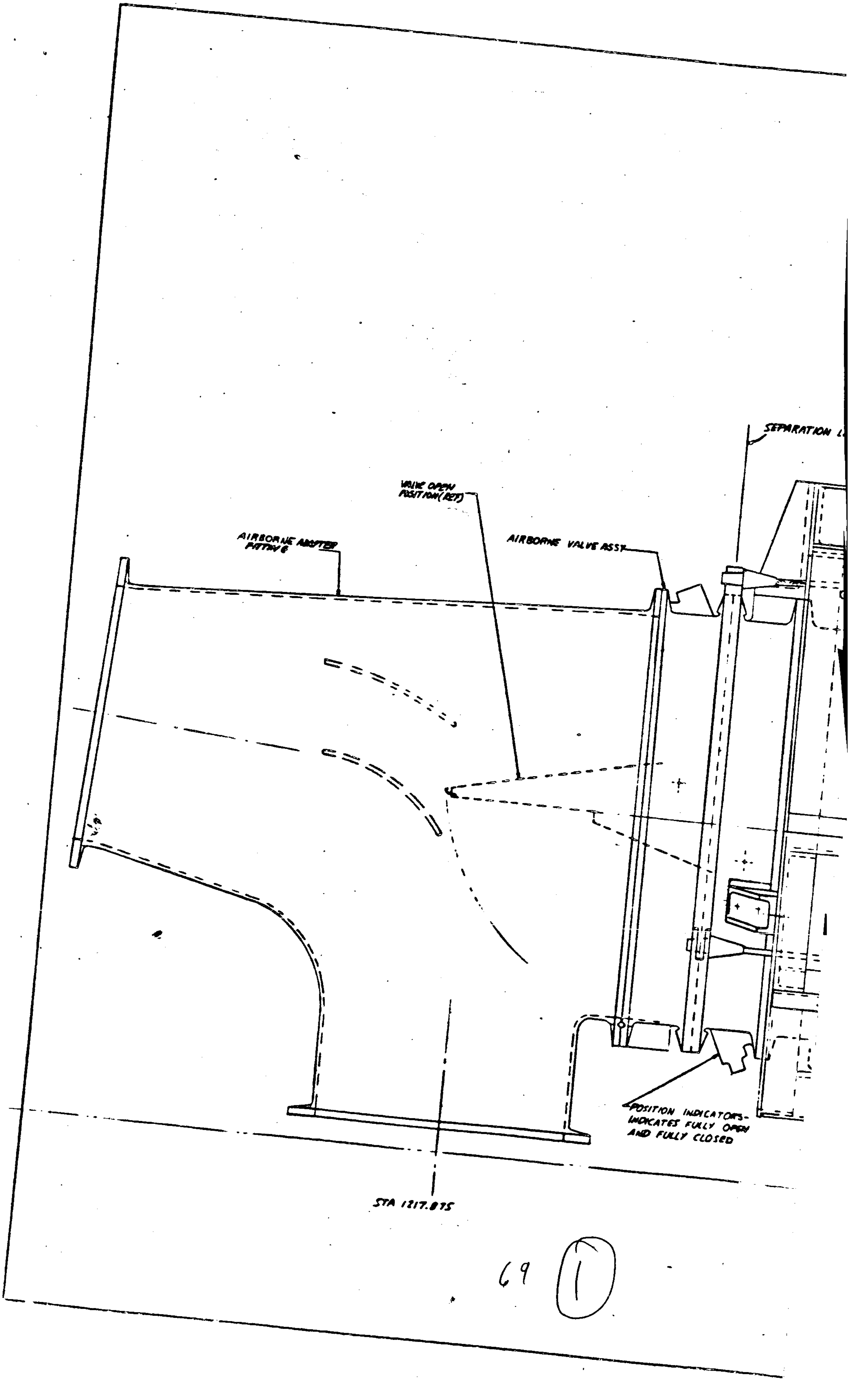
67 1



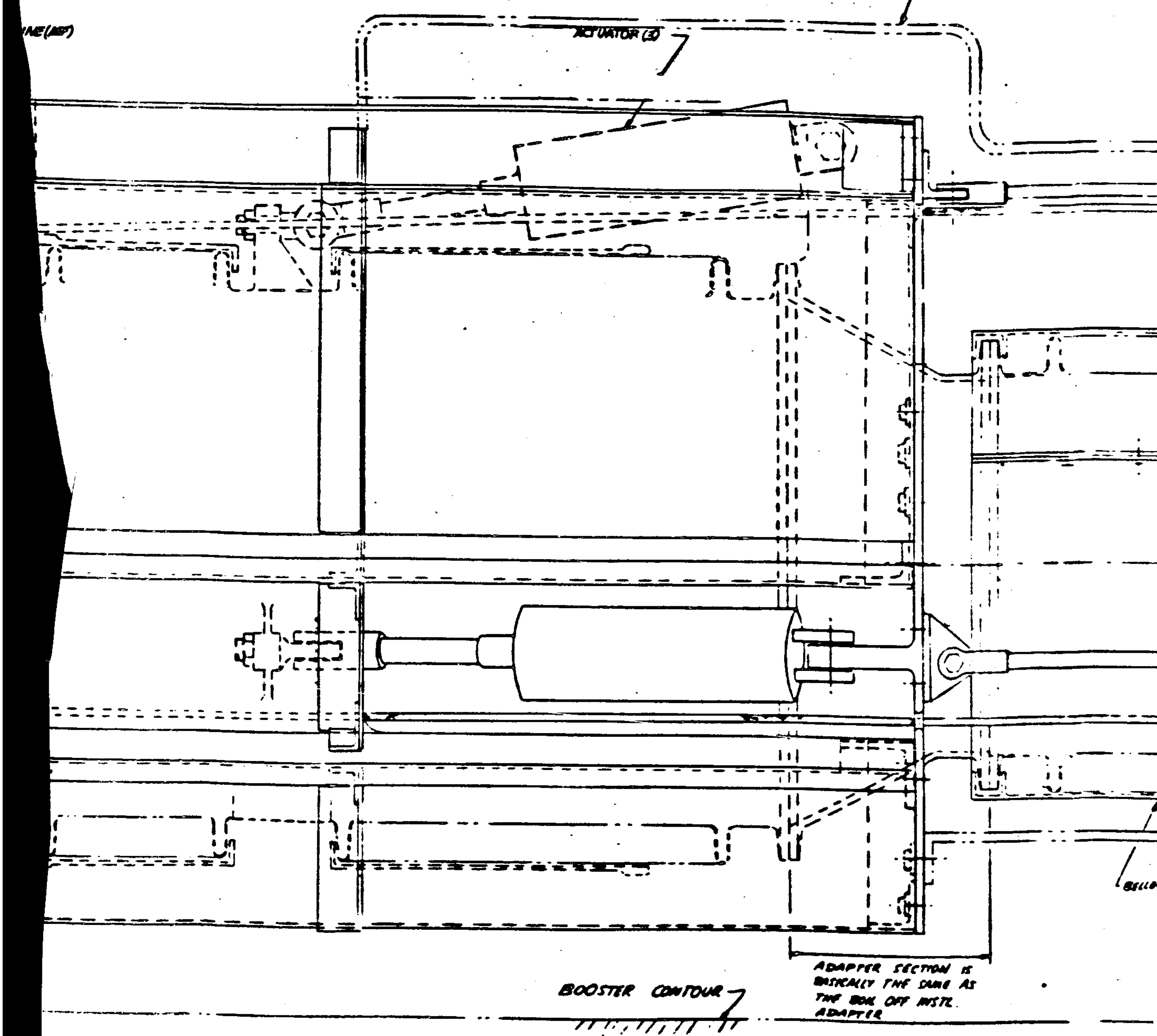
VIEW A-A

FIGURE 5-2
INTERSTAGE INSTALLATION

68 (3)

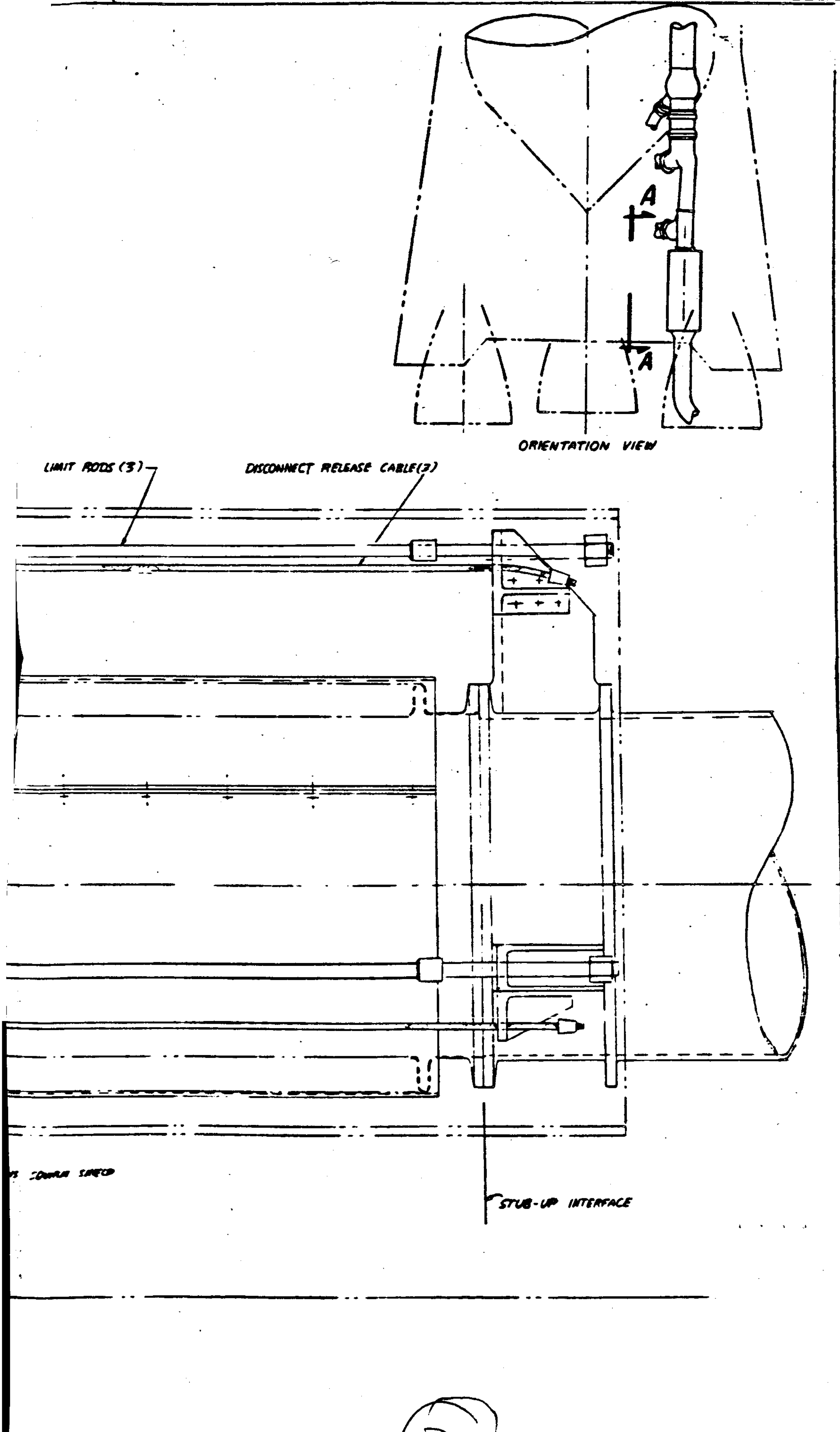

SEPARATION L
VALVE OPEN POSITION (REF)
AIRBORNE ADAPTER FITTING
AIRBORNE VALVE ASSY
POSITION INDICATORS- INDICATES FULLY OPEN AND FULLY CLOSED
STA 1217.875

69 1



VIEW AA
ROTATED 90°

69 2



69 3

OXIDIZER FILL AND DRAIN VALVE INST'L.
FIG. 5-3

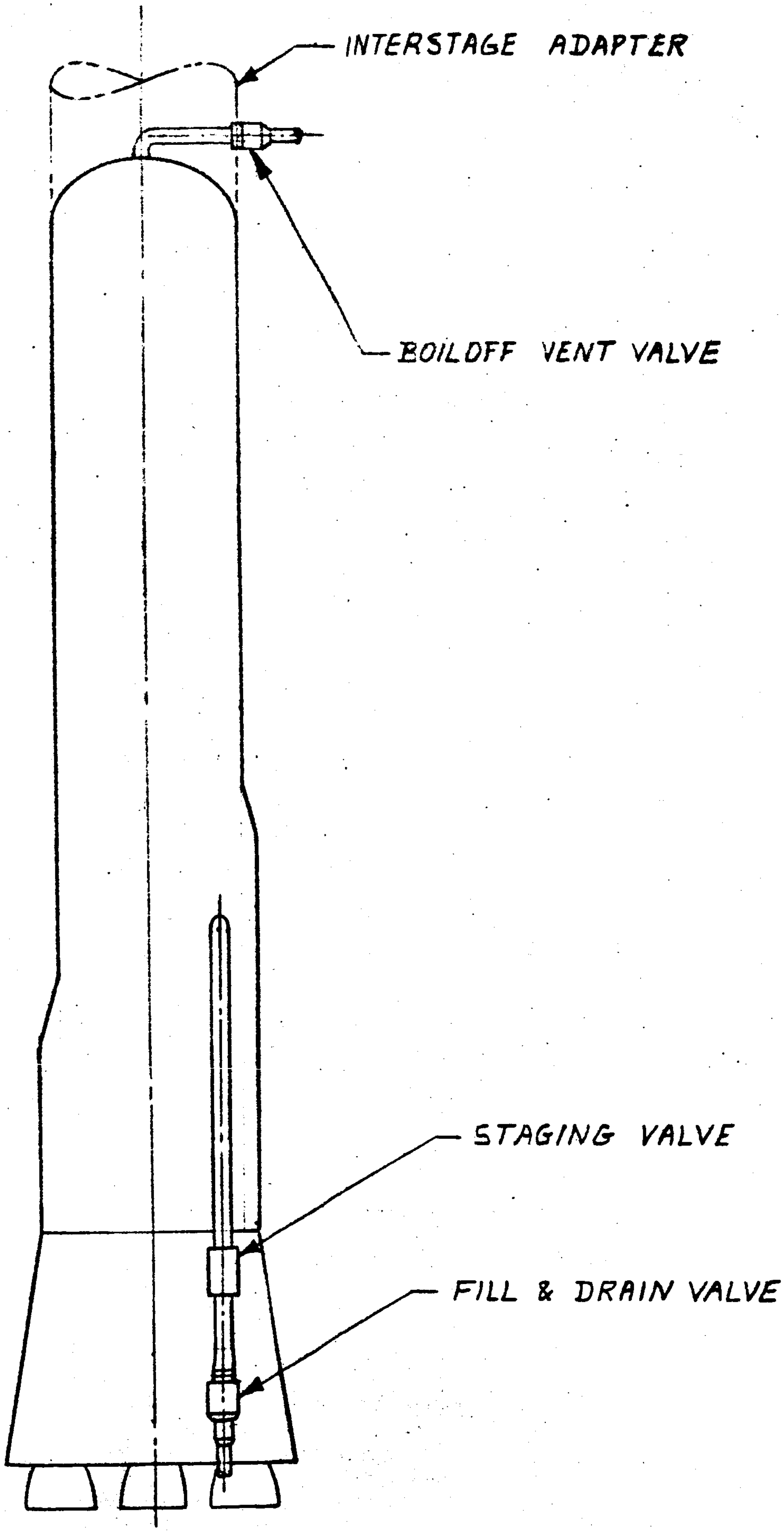


FIGURE 5-4
DISCONNECT APPLICATIONS

6. DESIGN REVIEW REPORT

DESIGN REVIEW REPORT NO. 696-2-3245-98	Page 1 of 7
TITLE: FLOX Disconnect	DATE OF REVIEW: 30 August 65
RESPONSIBLE GROUP: Propulsion	REF. DOCUMENTS/DRAWINGS: Report GD/C-BHV65-004
SYSTEM: FLOX Propulsion System	ECP 8436

Conclusion:

With the incorporation of the action items and direction identified by this Review, the Preliminary Design of the FLOX Disconnect satisfactorily meets the ground rules and requirements of Sales Order (S.O.) 458-1-17, (Task Order #3 to the -3245 Contract) and subsequent direction. The design concept presented is documented by Convair Report GD/C-BHV65-004 which at the time of this review was in a preliminary draft. The final report will incorporate:

a) The results of the action items and direction of this review.

b) The drawings used in the review as Handouts.

c) This Design Review Report &

d) Improved and completed data not available at the review.

NOTE: All action items have been closed by their incorporation into the Final Report.

Design Review Chairman D R Thomas (5.0) Date 9 SEPT 1965

Responsible Group R H Callahan Date 9 SEPT 1965

Design Review Group L. W. Stuckley Date 9 SEPT 1965

NO.	ACTION ITEM	ACTION BY	SCHEDULE
1.	Include in the Final Report, a discussion of butterfly closing rates with respect to staging rates for the staging disconnect application.	Anderson/ Siden 663-0	CLOSED
2.	Include in the Final Report the identification of the benefit and/or problem of fluid entrapment between butterflys at disconnect closure.	Anderson/ Siden 663-0	CLOSED
3.	To minimize spillage, the butterfly facing should be placed on the flat side of the fly, if consistant with Action Item Two.	Anderson/ Siden 663-0	CLOSED

DESIGN REVIEW REPORT

NO.	ACTION ITEM	ACTION BY	SCHEDULE
4.	Place a fiberglass shield, or equivalent, over the cables to shield them from accidental activation.	Anderson/ Siden 663-0	CLOSED
5.	Proceed considering the use of flys with seals on both halves of the disconnects for all three applications.	Anderson/ Siden 663-0	CLOSED
6.	Provide a line reducer behind the ground portion of the boil-off and fill and drain disconnects.	Anderson/ Siden 663-0	CLOSED
7.	Reference the Edwards Air Force Base Seal Report in the Final Report.	Anderson/ Siden 663-0	CLOSED
8.	Incorporate in the report "Closed", "Mid-Position", and "Open position" photographs of the presentation model	Anderson/ Siden 663-0	CLOSED

DIRECTION:

1. Commonality of design for the three applications, as well as for components (flys, seals, etc.) within each application, is to be a guiding ground rule in the continued development of the disconnect.

PURPOSE:

In compliance with the S.O. and Division Policy, this Design Review was held. The objective of the Review was to evaluate the technical adequacy and accuracy of the preliminary concept;and to demonstrate to the Customer this technical feasibility, as well as Convair's compliance to the technical requirements of the contract.

PRESENTATION:

Mr. Siden of the Propulsion Group gave the main presentation. This presentation summarized the material found in the presentation handouts which were the preliminary issues of significant portions (Report and Drawings) of the Final Report (GD/C-BHV65-004) (Copies of the handouts are on file with the master of this report).

DESIGN REVIEW REPORT

PRESENTATION: (Continued)

His presentation centered on the ability of the disconnect concept to function in a FLOX environment for the three principle applications of:

a. A Staging Disconnect
b. A rise off Fill and Drain Disconnect
c. A FLOX Boil-off Disconnect with or without a Boil-off Valve between the disconnect and the FLOX tank.

DISCUSSION HIGHLIGHTS:

Specific highlights of the evaluations following the presentations include:

Staging Disconnect Application

The operating characteristics of the butterflys (flys) was discussed in some detail.

It was pointed out that the booster separates from the sustainer at a relative 1.3 Gs (Approx.) and that fly closure occurs in about the first 4 inches of staging, making fly actuation approximately a .10 sec. operation. A recognition and discussion of this detail is to appear in the Final Report (Action Item One.)

The concept of the fly design brought out the need for careful consideration of the trade offs in establishing detail design. At this Review, the fly concept was a waffle construction with the facing on the angled side of the fly(Figure -1)

FIGURE 1

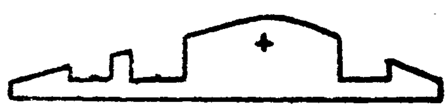


FIGURE 2

DISCUSSION HIGHLIGHTS: (Continued)

As two flys came together (flat side faces meeting) fluid trapped within the waffle structure may either:

1) Act as a hydraulic buffer and keep the seals from seating, or
2) Act as a hydraulic buffer, allowing sealing and preventing excessive closing impact loads.

The benefit or problem of fluid entrapment can only be determined in development tests. Action Item 2 was assigned to identify this situation in the Final Report.

Spillage, when disconnecting, would be minimized if the facing was on the flat side of the fly (Figure -2). It was decided that until buffing problems, if any, are identified, it would be preferable to proceed with the concept of flat side facing. (Action Item 3 was assigned.).

During maintenance or checkout modes on the ground, the actuating lanyards may be inadvertently pulled which may, in turn, cause the shear pins to fail or the clamp to release. Action Item 4 was assigned to protect the cable from accidental actuation.

The concept minimizes FLOX spillage, especially with the incorporation of Action Item 3. It was pointed out, however, that approximately 20 gallons of FLOX will be trapped in the booster section upon staging. The fly and seal on the booster half will prevent spillage of this residual. The same amount of residual LOX exists in the SLV-3.

Rise-Off Fill and Drain Application

The fill and drain disconnect is identical in concept to the staging disconnect except as follows:

The fill and drain valve portion of the disconnect must operate more than once and without the benefit of rise off to initiate the fly action. This requires an independent actuating device to perform this function. An open housing (cage) surrounds the ground portion of the disconnect and attached to it are three actuators to position the bellows and hence the valve portion of the disconnect. The cage provides the structure to receive the reaction of the actuators as well as protect the disconnect.

The S.O. calls for no closure (fly) on the ground portion of the disconnect. However, it was felt that, at least, the fly, without a seal, should be retained to protect the ground portion of the disconnect from blast and contamination and to reduce spillage. No

DISCUSSION HIGHLIGHTS: (Continued)

disadvantage could be seen in leaving the seal in, as it too would aid in contamination protection. It was decided to proceed with the concept on the basis of flys and seals on both sides of the disconnect. (See Action Item 5)

The presented concept depicted the fill & drain flex section below the disconnect as the same size (11" ∅) as the disconnect. This would require a redesign of the airborne manifold forward of the disconnect due to a load increase caused by the internal pressure acting on a larger area. Action Item 6 was assigned to provide a reducer below the disconnect to avoid the need for an A/B duct re-design.

FLOX Boil-Off Disconnect Application

In accordance with the S.O., the boil-off disconnect concepts were to function with or without a boil off valve (BOV) between the disconnect and the FLOX tank. With the BOV, a fly was to be provided in only the ground portion of the disconnect. Without the BOV, flys and seals would be provided on both sides.

For the present, it was decided to proceed with the concept of seals and flys on both sides of the disconnect. (Action Item 5). This decision poses a problem for the relief valve exhaust but it has been decided to reserve this problem for future decision. (See Design Review Report 696-2-3249-97 for a discussion of this problem.)

The boil off disconnect will now be identical to the rise off disconnect including the reducer on the ground half of the disconnect and the cage and actuation system.

General Application

In demonstrating that the concepts were developed for a FLOX environment, the following factors are incorporated into the design:

1. The materials selected for the disconnect are compatible with a fluid medium of liquid oxygen and fluorine combined in any mixture ratio.

2. Only metallic seals, gaskets and "O" rings are employed for separable closures exposed to FLOX.

3. Carbon and rubber materials are not used in the design.

4. The design minimizes external and internal leakage.

DISCUSSION HIGHLIGHTS: (Continued)

5. Ease of cleaning, purging, inspection and contamination control has been a prime consideration in the design.

6. The concept is designed to conform to the most severe system and environmental specifications (GD/C Report No. 69-00202, Amendment B, dated 21 January 1964).

7. No lubricants are used in the assembly of any component or of the valve as a complete unit.

8. There are no threaded parts where the threads are exposed to FLOX.

9. No brazing is used.

10. Weight is minimized.

11. Prime consideration has been given to matching, existing ducting and clearance envelopes of the Atlas/Centaur vehicle.

12. The design minimizes the FLOX volume between closures in the two halves of the disconnect.

The disconnect seal design was recognized as one of the critical features of the concept, (as it would be on any concept.) An Edwards Air Force Base Report Documents Evaluations made on this type seal. NASA requested this report be referenced in the Final Report. (Action Item 7).

NASA stated that for any future effort on the disconnect design should strive for commonality of all components within the three applications; so, if possible, only one detail design will evolve, (Direction #1). It will remain to be seen if commonality will pay off economically. If one disconnect can be installed in three different applications it means that it must receive integrated qualification testing to perform any of its functions.

A two dimensional moving model of the disconnect, in the staging application, was used to help explain the disconnects operation. NASA requested that photographs of the model be included in the Final Report showing the flys in the "Closed", "Mid-position" and "Open" positions. (Action Items 8)

DESIGN REVIEW REPORT

ATTENDEES:

NAME	GROUP	DEPT. NO.
H. W. Groth	NASA-LeRC	
G. R. Smolak	NASA-LeRC	
H. Douglass	NASA-LeRC	
W. A. Roberts	SLV Program Office	633-0
H. W. Schmidt	NASA-LeRC	
H. W. Qualls	Propulsion Design	633-0
L. W. Standley	Design Review	672-0
T. D. Duncan	Parts Engineering	562-2
D. R. Thomas	Design Review	672-0
L. Siden	Propulsion Design	663-0
J. Nuding	Propulsion Design	663-0
J. E. Raynoha	Propulsion Design	663-0
D. W. Howard	Pneumatics Design	664-0
A. E. Buggele	NASA-SD	

DISTRIBUTION:

Attendees +	
J. H. Winters	145-0
W. A. Pickens	562-2
G. G. Congdon	674-1
J. A. Mendoza	674-3
W. G. Lux	141-3
D. Munizza	576-15 WTR
C. A. Johnston	576-1 WTR
T. Hemphill	561-0
F. Heid	NASA
T. J. O'Malley	571-0 ETR
D. Williams	571-1 ETR
C. Hanna	688-0
D. Suggs	683-1
Major J. M. Mickelson	AF-71
Major G. L. Claypool	SSD-SSVZE (5)
E. J. Hujsak	962-1
L. Weikum	671-0

7.0 ENGINEERING TEST REQUIREMENTS

7.1 Scope

This section outlines the qualification and individual acceptance testing required for the disconnect valve described under Parts 2 and 4 of this report. The tests are defined in sufficient detail for incorporation into a formal test document similar to that described in GD/C Report No. 69-00204 (Outline of Form and Instructions for the Preparation of Space Launch Vehicles--Vehicle-borne Equipment Specifications).

7.2 Definitions

For the purpose of this specification, the complete assembly consisting of two valve sections with position indicators, a flex duct actuator assembly including squirm shields, stop sleeves and limit rods, and a disconnect assembly including release accessories shall be referred to as the unit. The external load cage, load cage accessories, airborne and ground end adapter fittings, flexible hoses, bellows sections or any other items connecting to the basic unit interfaces for service condition simulation are considered test fixture items. The notations LN_2, GN_2, LF_2 and GF_2 correspond to liquid nitrogen, gaseous nitrogen, liquid fluorine and gaseous fluorine, respectively.

7.3 Qualification Testing

The tests are designed to simulate as close as practical the actual service conditions. Since the unit is used in three applications, environments from those three areas are incorporated into single tests, where feasible.

All parts or assemblies exposed to the flow area shall be LOX cleaned prior to any tests with fluorine. It is recommended that three (3) test specimens be made available for this program.

The position indicators shall be monitored during all phases of testing.

New static seals shall be used for the reassembly of any external joint. Use no lubricants.

The basic requirements are listed in the Performance Specification (Part 2 of this report), which includes pressure levels, leak rates, functions, etc.

7.3.1 Fluorine Compatibility Test

7.3.1.1 Installation and Checkout. Prior to installation, inspect the unit per Paragraph 7.3.8.1, Parts (a) through (l), where applicable, and Paragraph 7.3.8.2, Parts (a), (b), (c) and (d).

a) Assemble the unit in the test fixture with "L" set at 21.5 inches (see schematic in Figure 7-1). The external load cage and squirm shield is deleted for TV and film monitoring purposes. Actuate from fully open to fully closed to fully open three times.

b) With the unit open, slowly pressurize to 117 psig with GN2 and hold for five minutes while checking for external leaks. No leaks allowed.

c) Reduce the pressure to 32 psig, close the unit and vent the downstream side while maintaining the upstream side at 32 psig. Record any internal leakage across the closures.

d) Repeat (c) at 60 and 117 psig and record leakage rates at these pressures. Open the unit and depressurize.

7.3.1.2 Gas Flow and Actuation

a) With the unit open, passivate with GF_2.

b) Pressurize with GF_2 to 32 psig and hold while actuating from open to close to open three times. Check for external leaks.

c) Repeat (b) for 60 and 117 psig.

d) Reduce the pressure to 32 psig using GF_2 and repeat Step (c) of 7.3.1.1, above.

e) Open the unit and flow 15 lbs per second of GF_2 at 32 psig inlet pressure and -290° F temperature.

f) Repeat (e), flowing in the reverse direction.

g) Vent the unit and inspect the exterior for fluoride deposits or any other abnormal conditions.

7.3.1.3 Liquid Fill Plus Actuation

a) Fill the unit with LF_2 at 0 psig and actuate from open to close to open three times. In one of the closed positions, hold for 5 minutes.

b) Repeat (a) at 32, 64 and 117 psig.

c) Depressurize, drain and inspect exterior for any fluoride deposits or evidence of leakage.

7.3.1.4 Liquid Fill and Vibration

a) Adjust "L" to 19.5 inches, remove the actuators, install the squirm shield and lanyard protection covers, fill with LF_2, pressurize to 117 psig and vibrate along the ZZ axis per the envelopes described in Figures 7-2 and 7-3 and 7-4 (2 minutes/octave curve). Monitor for exterior leaks.

b) Repeat (a) vibrating along the YY axis (see Figure 7-1).

7.3.1.5 Liquid Fill Plus Disconnecting

a) Fill the unit with LF_2 pressurize to 117 psig, and disconnect by moving the aft face away from the forward face at an acceleration rate equivalent to 4.0 inches within .08 $\pm$ .01 seconds. Maintain the the 117 psig pressure on both halves for 3 minutes while monitoring for leaks.

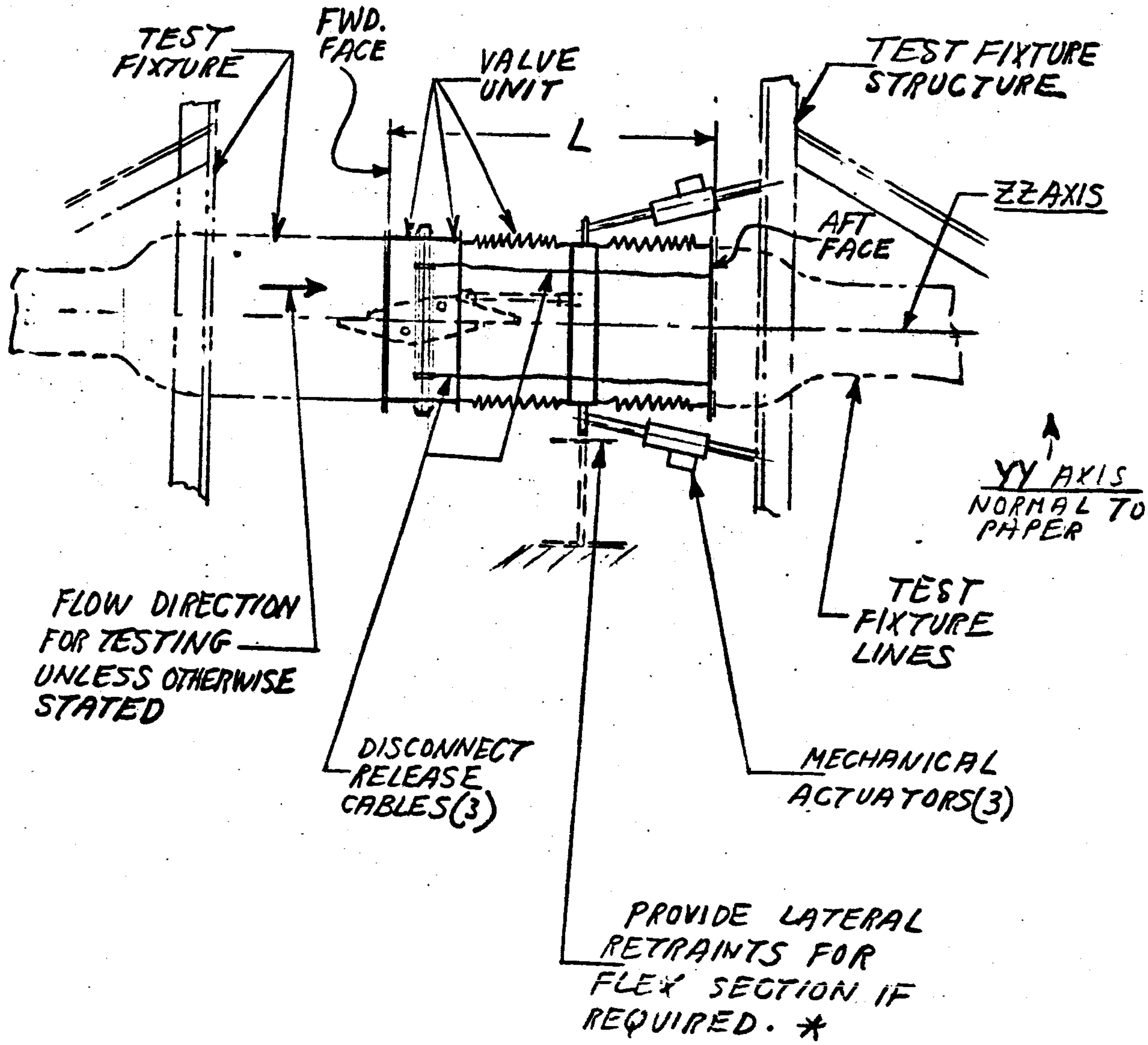
b) Reduce the LF_2 pressure in both halves to 60 psig and hold for 1 minute while monitoring for leaks.

c) Repeat (b) at 30 psig.

d) Depressurize, drain the two unit halves and pressurize each unit to 32 psig with GF_2. Hold for three minutes while monitoring for leaks.

e) Depressurize both unit halves, purge and inspect for abnormal conditions. Give special attention to the seal areas.

COMPATIBILITY TEST SET UP SCHEMATIC



* SQUIRM SHIELD NOT USED FOR ALL PHASES OF THE TEST FOR AIDING VISUAL MONITORING. SEE TEST DETAILS

FIG. 7-1

UNIVERSAL VALVE RANDOM VIBRATION REQUIREMENTS
(FOR COMBINATION WITH SINUSOIDAL VIBRATION)

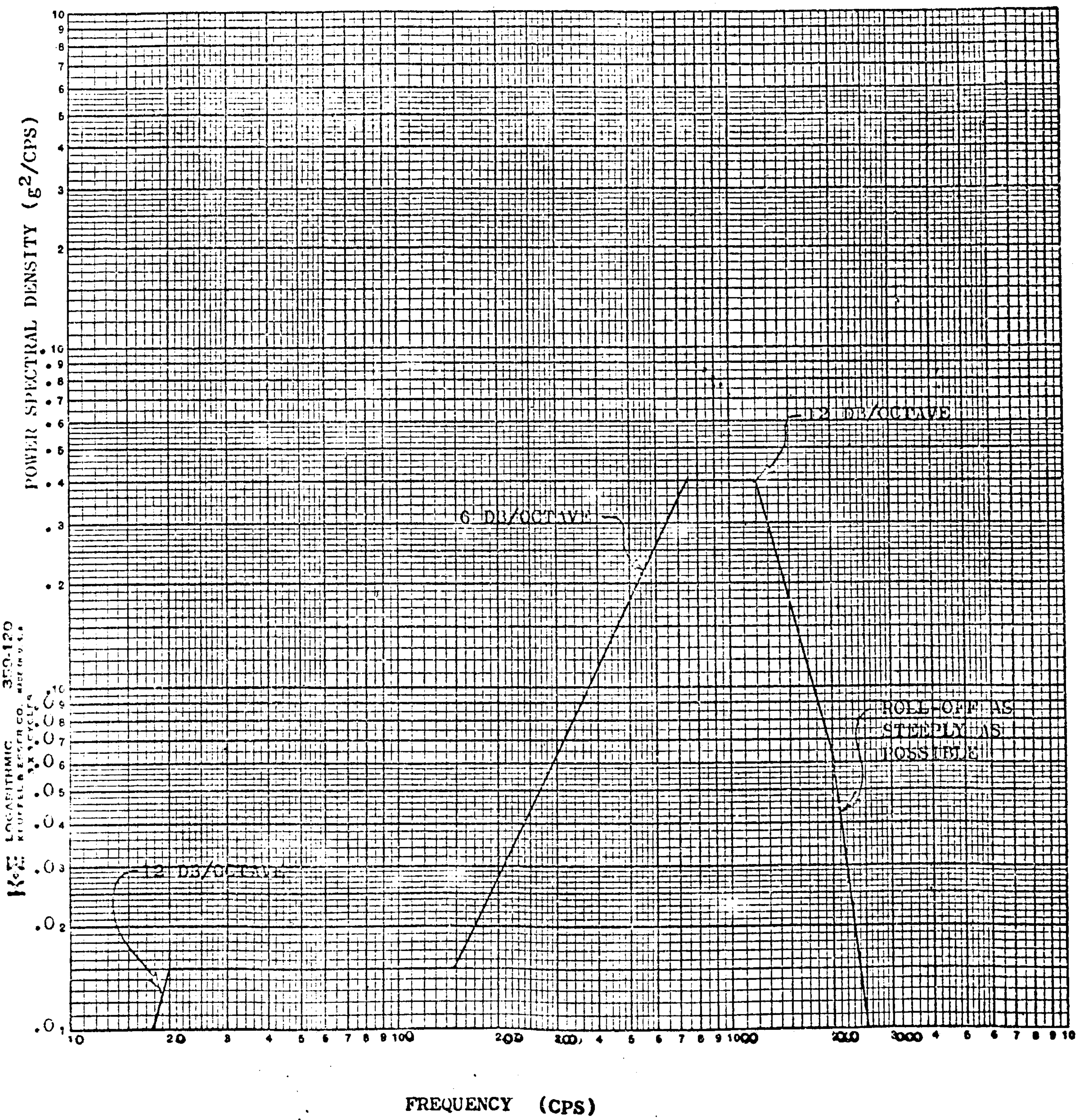


FIG. 7-2

JE 6/14/65

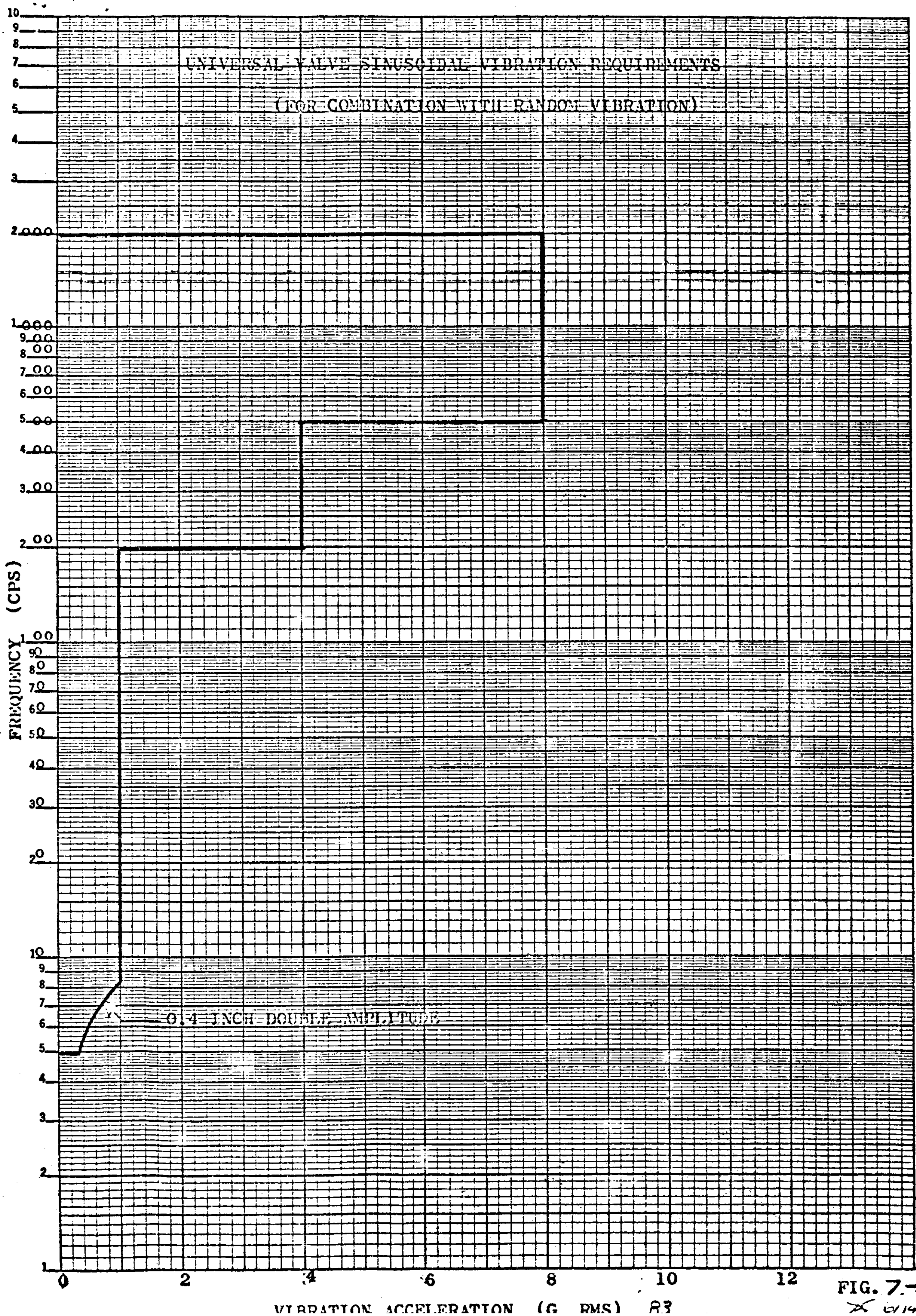
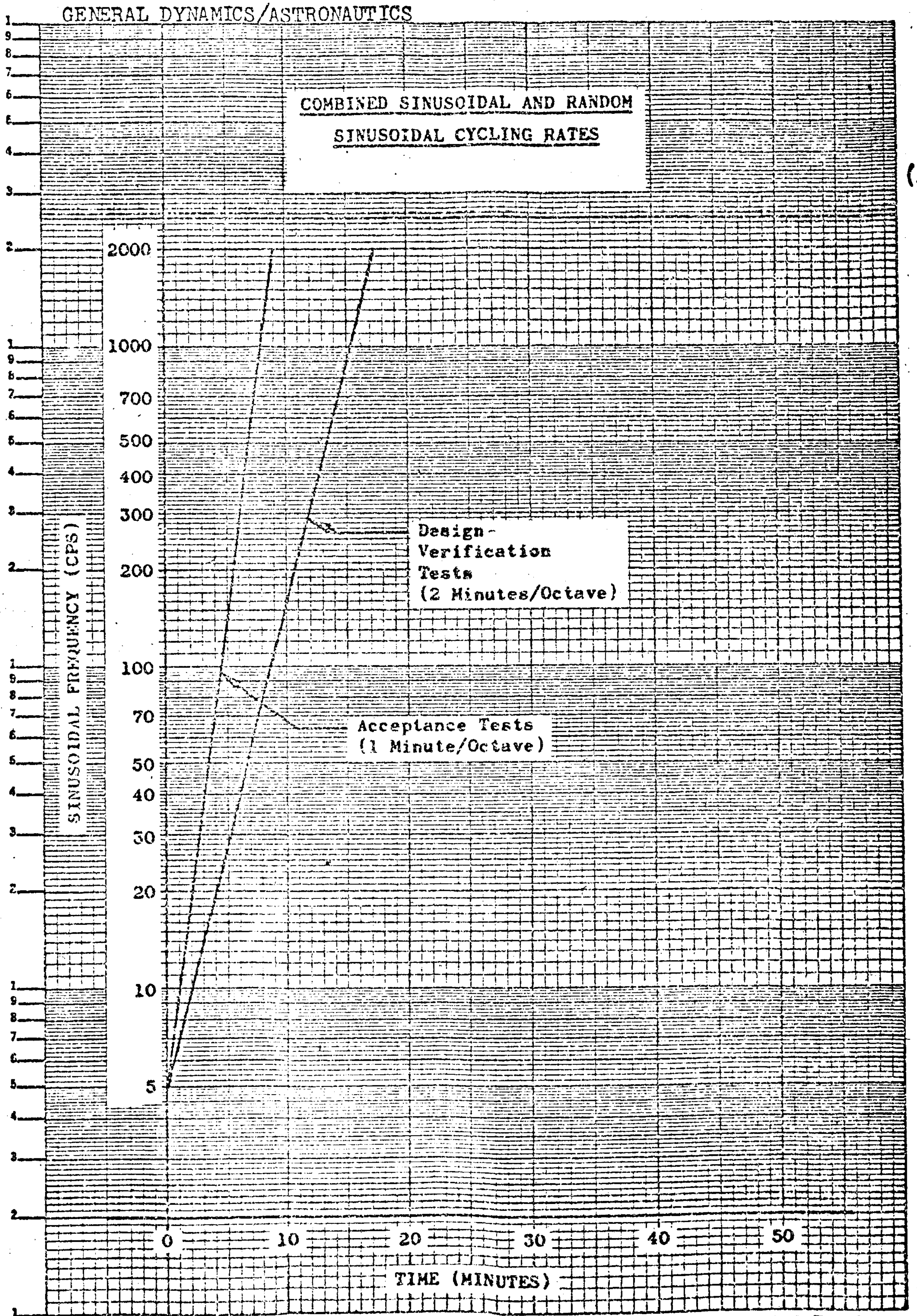

UNIVERSAL VALVE SINUSOIDAL VIBRATION REQUIREMENTS
(FOR COMBINATION WITH RANDOM VIBRATION)
FREQUENCY (CPS)
2,000
1,000
500
200
100
10
0.4 INCH DOUBLE AMPLITUDE
0
2
4
6
8
10
12
VIBRATION ACCELERATION (G RMS)

FIG. 7-3

GENERAL DYNAMICS/ASTRONAUTICS



(A)

FIG. 7-4

7.3.2 Vibration Tests

7.3.2.1 Installation and Checkout

a) Install a complete unit in the test fixture (see Figure 7-5) with the aft face misaligned with respect to the forward face, per the following:

1. .35 inch offset in the Y direction.

2. 1.5° angular per view DD of Figure 7-5.

3. .2 inch increase to the 19.5 inch "L" dimension.

The complete installation shall include a squirm shield complete with release cable shields, stop sleeves, lanyard cables, limit rods and position indicators for monitoring the butterfly positions.

b) Slowly pressurize the unit with GN_2 to 117 psig and hold for 3 minutes while checking for external leaks.

7.3.2.2 Vibration with Unit Connected

a) Fill the unit with LN_2 and pressurize to 117 psig. Hold for 3 minutes and check for external leaks.

b) While maintaining the conditions in Part (a), vibrate along the ZZ axis, per the envelopes of Figures 7-2, 7-3 and 7-4 (2 minutes/octave curve). Observe and record any leaks. Monitor the position indicators.

c) Repeat b for the XX and YY axis.

7.3.2.3 Vibration with Unit Disconnected

a) With the unit pressurized to 117 psig with LN_2, disconnect and check for leaks across the butterflies of both halves while maintaining the 117 psig.

b) Depressurize, remove the forward half of the unit from the fixture and install in a vibration test fixture.

c) With the forward half closed, pressurize with LN_2 to 117 psig, vibrate along the ZZ axis (using the envelopes per Figures 7-2, 7-3 and 7-4 (2 minutes/octave curve) while monitoring for leaks.

d) Stop vibration and hold the 117 psig for 3 minutes while monitoring for leaks.

e) Repeat Steps c and d for the YY and XX axis.

7.3.2.4 Leak Checking After Vibration

a) Reduce the pressure to 64 psig for 3 minutes while monitoring for leaks.

b) Repeat (a) at 32 psig.

c) Drain the LN_2 and pressurize with GN_2 to 32 psig and hold for 3 minutes while monitoring for leaks.

d) Repeat (c) with GN_2 at 64 and 117 psig and record leakage.

e) Depressurize and inspect the interior and exterior of both halves for abnormal conditions.

7.3.3 Flow Tests

7.3.3.1 Installation and Checkout

a) Install the unit as shown in mode "A", Figure 7-6, with misalignments between the forward and aft faces equal to that outlined in Paragraph 7.3.2.1, Part (a).

b) Pressurize to 117 psig with air or GN_2 and hold for 3 minutes while checking for leaks. Steps (a) and (b) are repeated for modes B and C. Misalignments between interfaces not required for modes B and C. The fill and drain adaptor fitting used in modes B and C shall be furnished by GD/C.

VIBRATION TEST SET UP SCHEMATIC

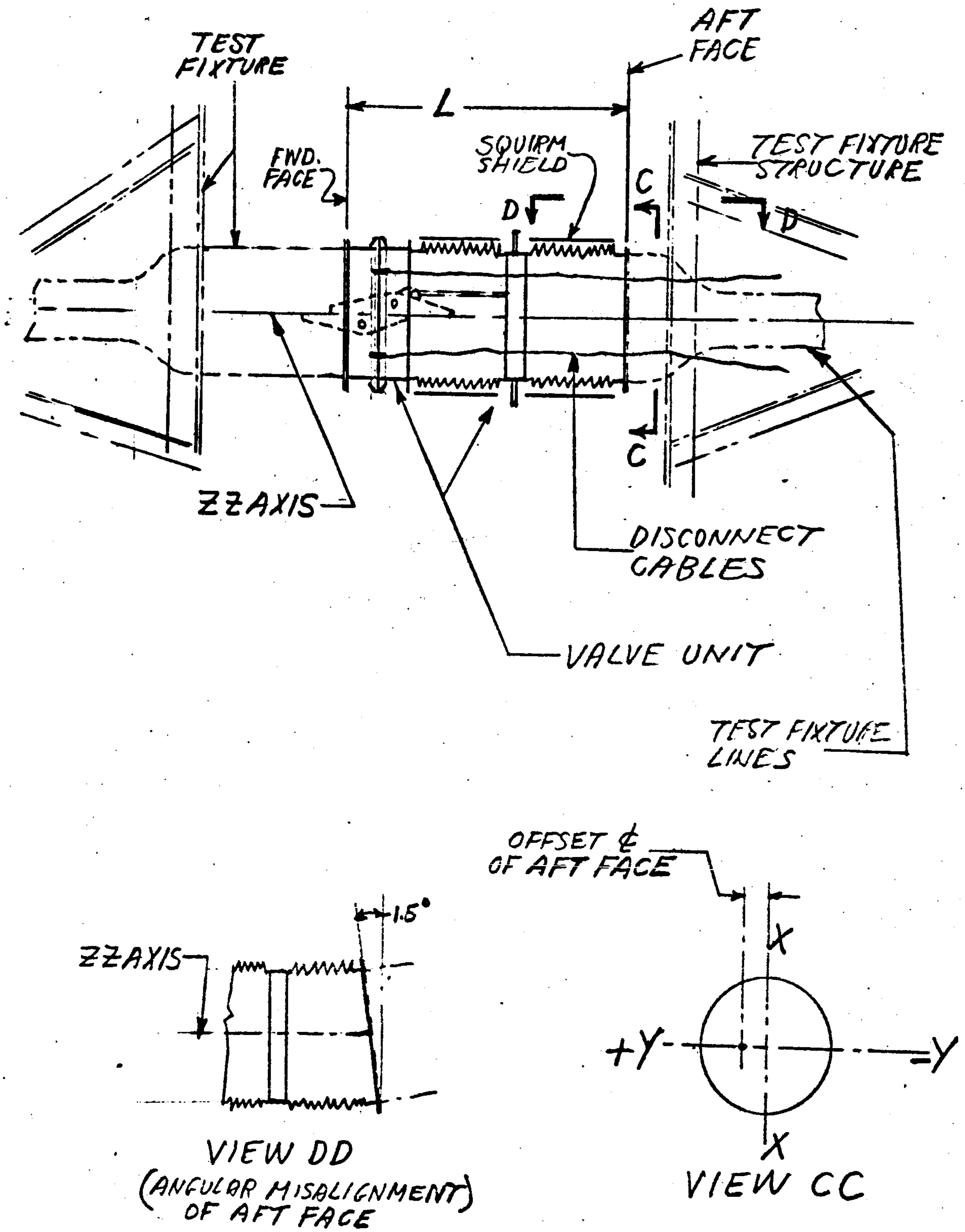


FIG. 7-5

7.3.2.2 Mode "A" Flow (see Figure 7-6)

a) Flow 5320 GPM of water through the valve unit. Flow direction is aft. Monitor the butterfly position, pressure drops across the assembly and any bellows movements.

b) Flow 2000 GPM in the reversed direction. Monitor the butterfly closure position, pressure drop and bellows movements.

7.3.3.3 Mode "B" Flow (see Figure 7-6)

a) Flow 2000 GPM of water in the forward direction. Monitor the butterfly closure position, pressure drop and any bellows movements.

b) Repeat (a), flowing 4000 GPM in the reverse direction.

7.3.3.4 Mode "C" Flow (see Figure 7-6)

a) With the butterfly closed, flow 2660 GPM of water through the airborne adapter fitting. Monitor butterfly position, leakage, and pressure drop.

7.3.4 Proof Cycle

7.3.4.1 Installation and Checkout for Modes A & B (see Fig. 7-7).

a) Install the complete unit in the test fixture. The complete installation shall include the external load cage, actuators, lanyards, protective shields, etc. If desired, the test fixture may incorporate a stub up flex section similar to that shown in Figure 5-3 (Oxidizer Fill and Drain Valve Installation Drawing). This flex section would be furnished by GD/C. The tests outlined in this report, however, assume that no formal stub-up assembly is used.

b) Actuate the unit from open to close to open 3 times. Monitor the position indicators and the actuator loads required to actuate the unit.

FLOW TEST SET UP SCHEMATIC

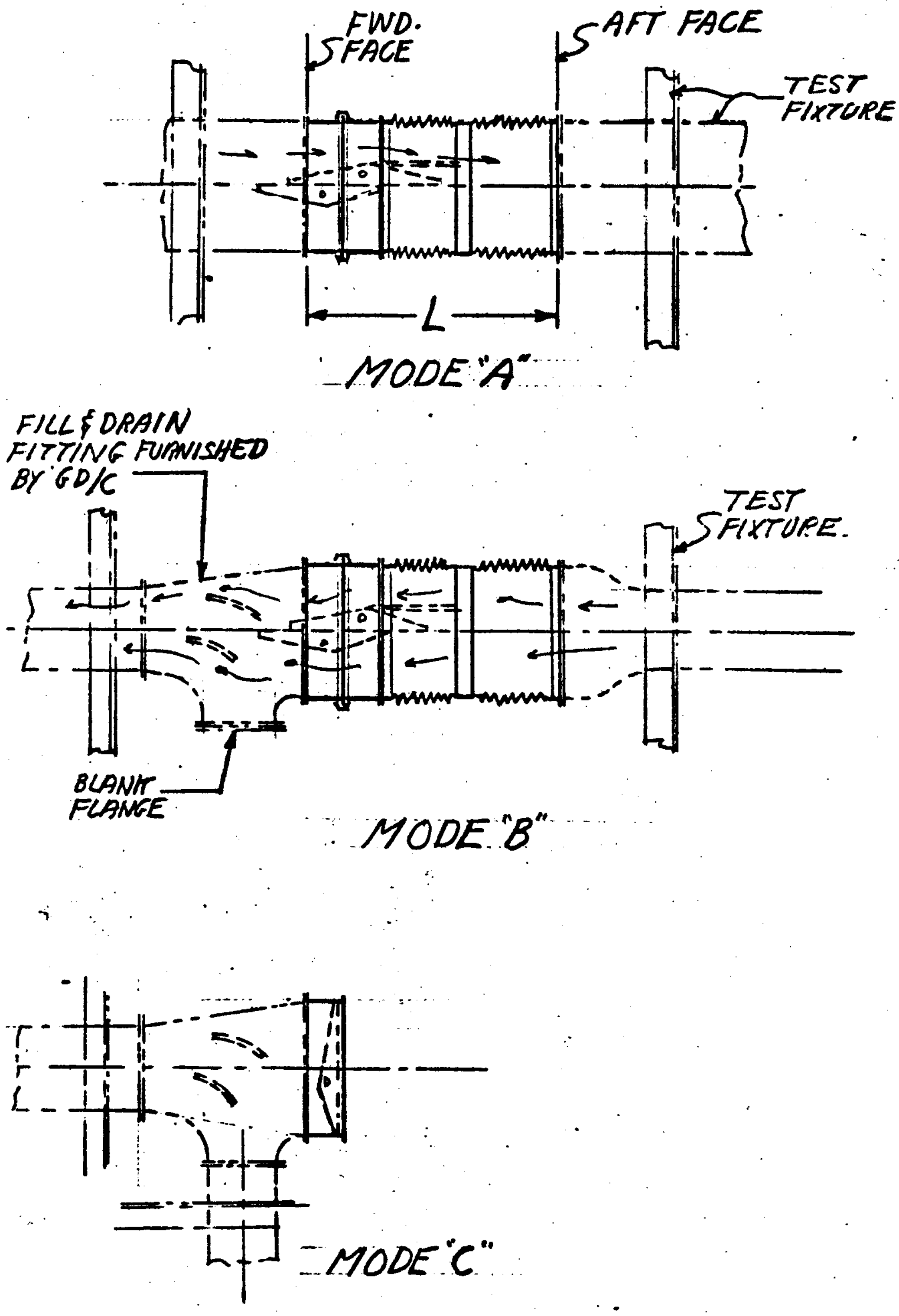


FIG. 7-6

c) With the unit open, pressurize to 75 psig with GN_2 and check for external leaks.

d) Repeat (c) for 117 psig.

e) Reduce the pressure to 32 psig, close the unit, vent the downstream side and record any internal leakage.

f) Repeat (e) with pressure on the downstream side and the upstream side vented.

7.3.4.2 Modes A and B Tests (see Figure 7-7)

a) With the unit open, fill with LN_2. Direct a light spray of ambient temperature water all around the disconnect region prior to and during the filling with LN_2.

b) Discontinue the spray. Pressurize to 75 psig and apply an axial load F_1 = 6000 lbs and F_3 = 1000 lbs to the load cage (direction of F_3 optional) and hold while monitoring for leaks. Monitor the position indicators.

c) While holding the conditions of Part (b), actuate the valve from open to close to open 3 times. Record the opening and closing loads and monitor for external leaks and position indicating. In one of the closed positions, hold for 5 minutes.

d) With the unit pressurized to 75 psig with LN_2, close, reduce F_1 to 1000 lbs, maintain F_3 = 1000 lbs, drain and depressurize the downstream side, and hold while monitoring for external and internal leaks.

e) While holding the conditions of Part (d), reduce F_1 to 0, apply F_2 = 2000 lbs, and disconnect the unit by moving the forward face at an acceleration rate equivalent to 4 inches within .28 $\pm$ .01 seconds (see Mode B, Figure 7-6).

f) Maintain the upstream LN_2 pressure at 75 psig for

TEST SET UP SCHEMATIC
PROOF CYCLE

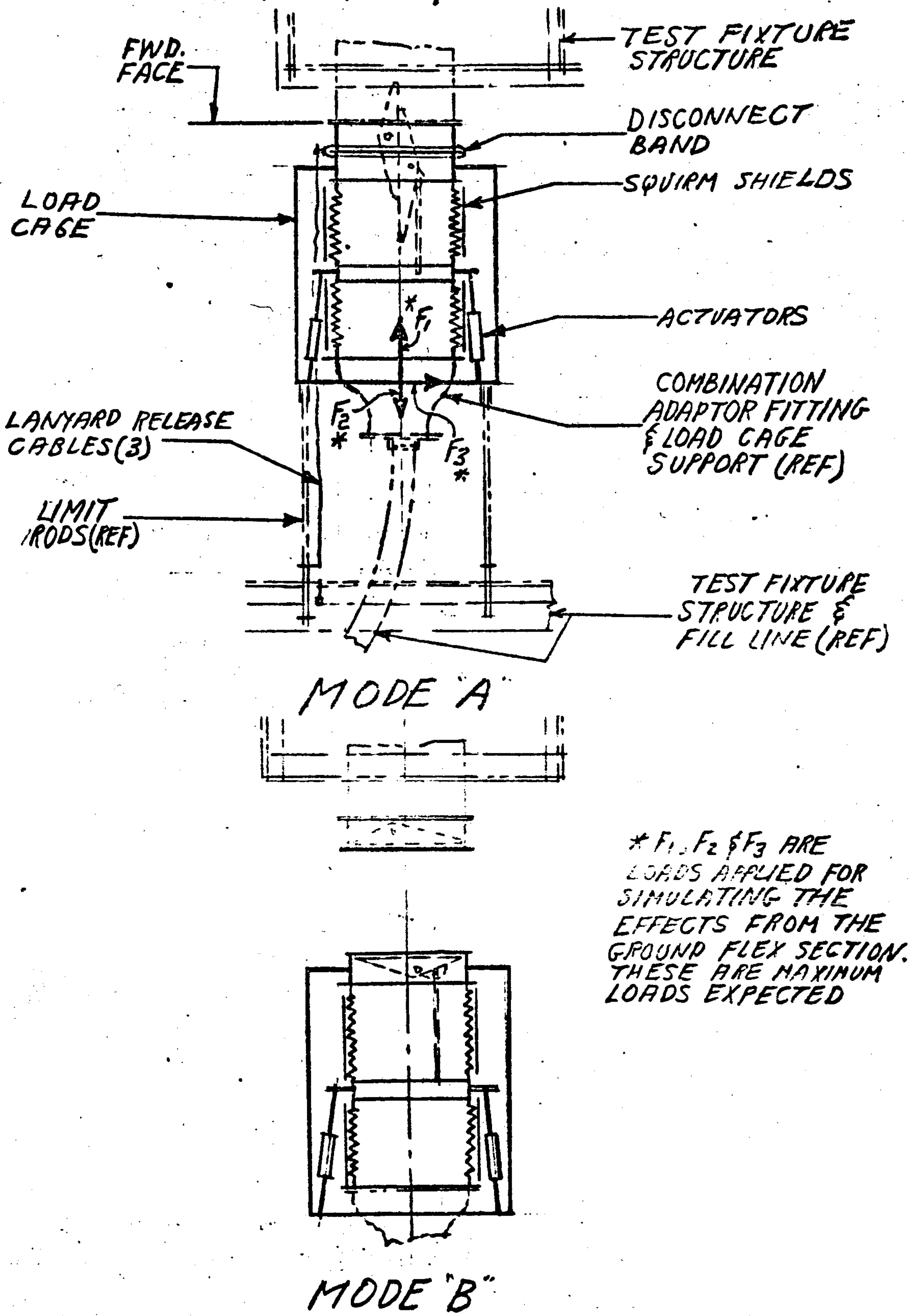


FIG. 7-7

3 minutes while checking for leaks.

g) Repeat (f) at 117 psig.

h) Vent, drain and inspect the interior and exterior of the unit halves. Give particular attention to the butterfly seal areas and the disconnect components.

7.3.4.3 Installation and Checkout for Modes C, D and E (Figure 7-8)

a) Install the unit complete with external load cage, squirm shield, lanyards, actuators, etc., as shown in Figure 7-8 (Mode C). The test fixture includes a flex hose section for simulating the actual ground vent line and a lanyard device for disconnecting the unit during vertical motion of the airborne section.

b) Actuate the unit from open to close to open 3 times. Monitor the position indicator.

c) Pressurize to 117 psig with GN_2 and check for external leaks.

d) Close the unit and pressurize the upstream side to 32 psig (GN_2) and check for internal leakage.

e) Open the unit and depressurize.

7.3.4.4 Modes C, D and E Tests

a) With the unit open, chill down with LN_2. Direct a light ambient temperature water spray on the unit prior to and during chilldown.

b) With the unit chilled down, rapidly drain, actuate to the closed position, pressurize the upstream side to 32 psig using GN_2, impose an 8100 in. -lb moment on the disconnect by applying the load F_r, and disconnect by pulling the lanyards with the test fixture actuators only. Note that the magnitude of F_r is determined by the difference between the 8100 in. -lb moment and that contributed by the test fixture flex hose section and the over-all assembly weight. It may not be required to apply F_r providing that the flex hose stiffness combined with any movements between the airborne and ground fixtures provide the 8100 inch lbs.

c) Maintain the 32 psig upstream pressure for 3 minutes while checking and recording leaks across the closure.

d) Pressurize the downstream half of the unit to 32 psig and check for leaks across the closure. Vent the pressure.

e) Repeat (c) for 117 psig.

f) Vent the assemblies and reassemble using a new disconnect seal.

g) Repeat Steps a, b, c, d and e, except in b, disconnect the unit by moving the airborne section at an acceleration rate equivalent to 30 inches within .79 $\pm$ .01 seconds in the direction shown on Figure 7-8. The valve lanyard cables are actuated in this maneuver by the simulated vehicle motion. Disconnecting shall occur during 15 to 24 inches of vertical displacement of the airborne section.

h) Vent the assemblies and inspect the interior and exterior for abnormal conditions.

7.3.4.5 Installation and Checkout for Modes F & G (Figure 7-9)

a) Install the unit complete with squirm shields, lanyards, lanyard shields, limit rods, etc. in the test fixture. The aft face shall be misaligned from the forward face per the following:

1. .35 inch offset in the X direction (see View RR of Figure 7-9).

2. 1.5° angular per view PP of Figure 7-9.

3. The nominal dimension "L" reduced by .20 inch.

TEST SET UP SCHEMATIC PROOF CYCLE

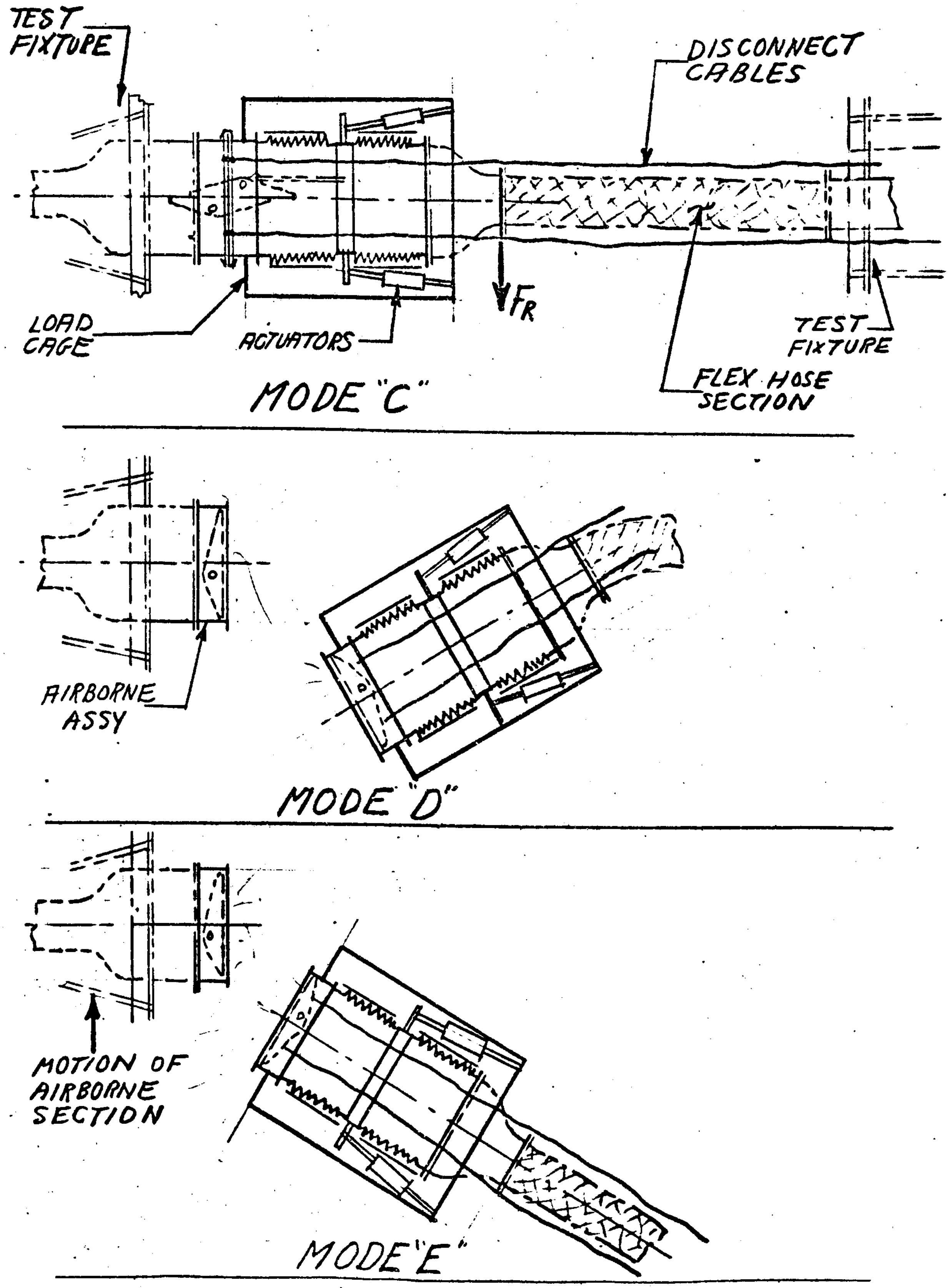


FIG. 7-8

b) Pressurize the unit to 117 psig and check for external leaks.

7.3.4.6 Modes F and G Tests

a) Fill the assembly with LN_2, pressurize slowly to 117 psig, while monitoring for external leaks.

b) While maintaining the 117 psig LN_2 pressure, disconnect by moving the aft face away from the forward face at an acceleration rate equivalent to 4.0 inches within .08 $\pm$ .01 seconds.

c) Maintain the 117 psig LN_2 pressure on both halves of the unit and record any leakage.

d) Vent the pressure, drain and visually inspect the unit and its accessories.

e) Reassemble the unit (using a new disconnect seal) and repeat Steps a, b, c and d with Face B misaligned from Face A, per the following:

1. .35 inch offset in the Y direction.

2. 1.5^{o} angular per view PP of Figure 7-9.

3. The nominal dimension "L" increased by .20 inch.

7.3.5 Life Tests

a) The unit shall be operated under the conditions of Paragraph 7.3.4 through 50 proof cycles.

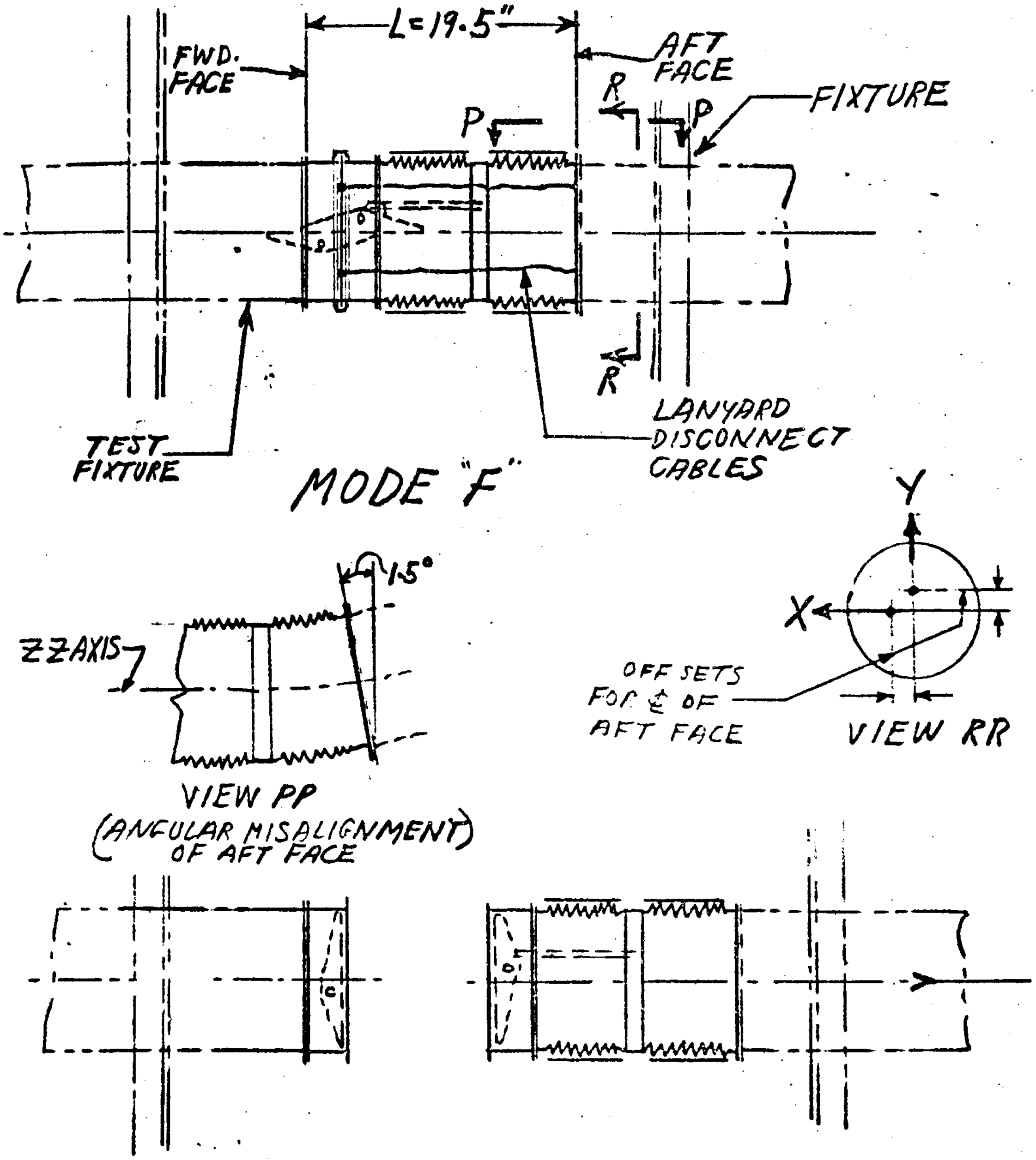
b) Any malfunctioning of the unit shall cause the unit to be retested until the requirements are met.

7.3.6 Proof Pressure Test

7.3.6.1 Installation and Checkout

a) Mount a complete unit in the test fixture with the aft face misaligned from the forward face, per Para. 7.3.4.5, Part (a) (see Figure 7-9).

TEST SET UP SCHEMATIC PROOF CYCLE



MODE "G"

FIG. 7-9

7.3.6.2 Pressure Testing

a) Slowly pressurize to 178 psig using GN_2. Note any damage and record leakage. Depressurize and closely examine for any permanent set.

b) Repeat (a) using LN_2.

c) Disconnect the unit (not required to simulate vehicle motion).

d) Repeat Steps (a) and (b) above for each half of the unit.

7.3.7 Burst Pressure Test

7.3.7.1 Installation and Checkout

a) Install a unit per the requirements of Paragraph 7.3.6.1, Part (a) above.

7.3.7.2 Pressure Testing

a) Slowly pressurize with LN_2 to 228 psig and hold for 15 seconds.

b) Slowly increase the pressure until burst or extreme distortion and note the results. Depressurize and inspect the unit.

c) Using a second unit disconnected, repeat Steps a) and b) for each half.

7.3.8 Individual Acceptance Tests

7.3.8.1 Visual Bench Check

a) Examine the two interface flanges of the assembled unit for any surface imperfections.

b) Check the over-all free length which should be approximately 35-3/4 inches. In this free length conditions, the driving butterfly should be in an approximate 45° position.

c) Move the driven butterfly blade within the limits allowed by the mating driver butterfly. The blade should move freely.

d) Check both butterfly blades and the actuating rod for mounting pins and the retainer pins.

e) Inspect the interior surfaces for scratches, dents, weld inclusions, etc. Pay particular attention to the butterfly sealing area in the housing and the seal on the butterfly blades. All sealing surfaces should be free from nicks, scratches, abrasions, dents, etc.

f) Inspect the butterfly blades for position indicator slugs. Two slugs required per blade. Check the slug retaining devices for proper retaining.

g) Check the butterfly blade structure for any bent webs, deformed skins, undercuts, burrs, warpage, etc.

h) Remove the lanyard cable protective covers (3) if attached and check the lanyard cable assemblies for release pins, release pin retainers, stop collars, shear pins, shear pin retainers, and the aft end fittings.

i) Inspect the limit rods for proper mounting. One rod is equipped with a stop sleeve (see Figure 4-1).

j) Check the bellows squirm shield for proper mounting and for any unusual surface conditions.

k) Check the "V" type release band for pin installations, catch cables, clamping bolt assembly, etc.

l) Inspect the position indicator electrical interface for defective threads, bent contact points, etc.

7.3.8.2 Bench Check Using Tools and Fixtures

a) Attach a fixture from the mounting bosses on the aft valve housing and to the aft flange of the bellows section. Slowly compress the bellows section until the external lug on the bellows assembly stops against the stop sleeve on the retainer rod. Check the load required for this maneuver. The load shall be 830 lbs ± 5% and the butterflies shall be in the fully open position. Check the gap between the butterfly position indicator slug and the position indicator sensor probe. The clearance shall be .020 ± .005 inch. Electrically check the position indicator sensor.

b) Using the fixture, continue to compress the aft bellows an additional 3/4 inch. The total load should now be 1450 lbs ± 5%.

c) Slowly remove the load and check the free length of the assembly and the driven butterfly for free movement.

d) Using the fixture, slowly extend the flex section until the butterfly blades are .005 to .010 inch from the stop lips on the housings (check with feeler gage). Record the maximum load during this maneuver. Limits of this load to be furnished per the detail seal design and prototype tests. Examine the shear pin assemblies. There should be no evidence of pin yielding. Check the gap between the position indicator sensor. The clearance shall be .020 ± .005 inch. Electrically check the position indicator sensor.

e) Hold the closed position and pressurize the upstream side to 32 psig while monitoring for leaks across the butterfly seals. Repeat for the downstream side.

f) Slowly release the load and check the free length. No yielding of bellows permitted. It may be required to apply a reverse force to the external actuator lugs for breaking out the seals.

g) Inspect the interior sealing surfaces for any unusual appearance.

7.3.8.3 Pressure Check

a) Mount the unit in a fixture (similar to that shown in Figure 7-9) and misalign the aft flange relative to the forward flange per that specified in Paragraph 7.3.4.5, Part (a).

b) With the unit open, slowly pressurize to 117 psig with GN_2 while monitoring for leaks.

c) Depressurize, fill with LN_2, and pressurize slowly to 117 psig while monitoring for leaks.

d) Maintain the 117 psig LN_2 pressure and disconnect the unit by moving the aft flange.

e) Maintain the 117 psig in both halves while monitoring for leaks and visually inspecting the limit devices on the aft half.

f) Depressurize, reconnect using a new seal (torquing the release band bolts to specified values), and repeat Part (b). Prior to assembly, inspect the indexing pins of the disconnect flange for any burrs or bends. All components shall be LOX clean and moisture free prior to assembly.

REFERENCES

1. Development of Mechanical Fittings Phase I & II
Report No. RTD-TDR-63-1115 - December 1963.

Air Force Flight Test Center
Air Force Rocket Propulsion Laboratory
Edwards Air Force Base, California

2. NASA Technical Note D-1727
Experimental Evaluation of Liquid-Fluorine Systems Components

By Richard L. DeWitt and Harold W. Schmidt
Lewis Research Center
Cleveland, Ohio
June 1963

3. NASA Technical Note D-2453
Friction, Wear, and Dynamic Seal Studies in Liquid Fluorine and Liquid Oxygen.

By W. F. Hady, G. P. Allen, H. E. Sliney, & R. L. Johnson
Lewis Research Center
Cleveland, Ohio
August 1964

4. Proceedings of the Conference on the Design of Leak - Tight Fluid Connectors - August 4-5, 1965

George C. Marshall Space Flight Center,
Huntsville, Alabama

5. Compatibility of Atlas Materials with Fluorine Propellants.
General Dynamics/Convair Report No. ERR-AN-64-483

6. Design Handbook for Liquid Fluorine Ground Handling Equipment

Department 528-0
General Dynamics/Convair
August 23, 1963

WADD Technical Report 60-159 prepared by the Aerojet General Corporation under Contract AF33(616)-6586 to Wright Air Development Division.

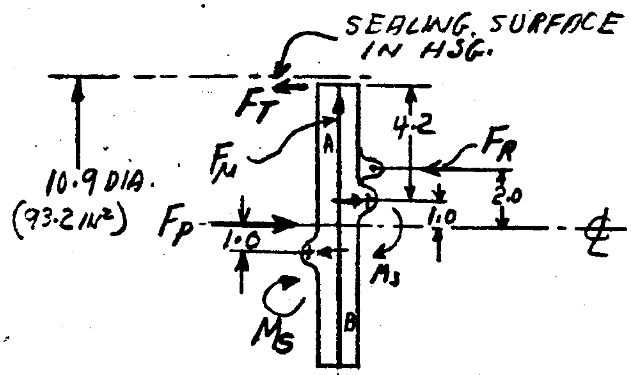
7. Valve Assembly - Fill and Drain, Liquid Oxygen, High Rate, Specification for Report No. 27-02102 General Dynamics/Convair

8. Valve Assembly, Low Pressure Drop Disconnect, Oxidizer, Missile-borne, Specification for Report No. 27-02248 General Dynamics/Convair

Calculations. Calculations shown for these designs are of a preliminary nature. Detail trade-offs and the optimization of material distributions were not attempted. However, the components shown are representative of what can be expected for a prototype unit.

BUTTERFLY LOAD ESTIMATE

SHT. 1 OF 2



F_P = LOAD DUE TO PRESSURE

F_R = ACTUATING ROD LOAD

M_S = MOMENT DUE TO SEAL BREAK OUT

F_T = TOE LOAD FROM BLADE "B"

F_μ = FRICTION LOAD = $.2 F_T$

ASSUMING 75#/IN SEAL LOAD & $\mu = .2$ (PIN FRICTION NEGLECTED BECAUSE OF MAGNITUDE)

$$M_S = \pi \times \frac{10.9}{2} \times 75 \times .2 \times \frac{2 \times 5.45}{\pi} \times 2 = 1780 \text{ in\#/BLADE}$$
*

FOR BLADE "A" (WITH SEAL)	FOR BLADE "B" (WITH SEAL)
$F_T \times 6.2 = F_P \times 1 + M_S + .2F_T$	$F_R \times 1 = F_T \times 4.2 + F_T \times 1 \times .2 + M_S$
$F_T = \frac{F_P + M_S}{6.0}$	$\therefore F_R = 4.4 F_T + M_S$

COMBINING, $F_R = 4.4\left[\frac{F_P + M_S}{6.0}\right] + M_S = .733F_P + .733M_S + M_S$

$$\therefore F_R = .733 F_P + 1.733 M_S$$

FOR FILL & DRAIN APPLICATION

$$F_P = 75 \times 93.2 = 6980\#$$

$$\therefore F_R = .733 \times 6980 + 1.733 \times 1780 = 8200\# \text{ (OPERATING)}$$

$$F_T = \frac{6980 + 1780}{6.2} = 1460\#$$

FOR VENT APPLICATION (USING TWO CLOSURES)

$$F_P = 35 \times 93.2 = 3260$$

$$F_R = .733 \times 3260 + 1.733 \times 1780 = 2390 + 3090 = 5480\#$$

$$F_T = \frac{3260 + 1780}{6.0} = 840\#$$

* APPROX. ARM FOR RESULTANT OF SEAL BREAK OUT LOAD

BUTTERFLY LOAD ESTIMATE CONT.

STAGING APPLICATION:

F_R TO HOLD VALVE OPEN $= .75 \times 830 = 622^{\#}$ (NOMINAL)

THE FIRST 3¾" OF STAGING REQUIRES APPROX. .071 SEC.

APPROX. VALVE CLOSING TIME = .071 SEC.

F_R DUE TO SEALS AT CLOSING $= 6.4 \times \frac{M_S}{4.2} + M_S = 2.53\, M_S = 4500^{\#} \leftarrow$ NEGLECTING F_N WHICH IS NEGLIGABLE.

USING FACTOR OF (2) DUE TO POSSIBLE IMPACT, $F_R = 4500 \times 2 = 9000^{\#} \leftarrow$ THIS VALUE SUFFICIENT TO INCLUDE MINOR LOADS DUE TO INERTIA & PADDLE EFFECT SHOWN BELOW.

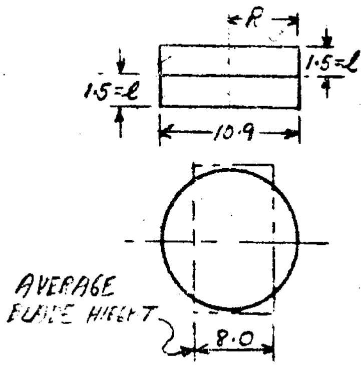
LOAD ON BLADE DUE TO 117 PSI SUSTAINER PHASE $= 117 \times 93.2 = 10{,}900^{\#}$ (OPERATING)

FLOW FORCES NOT INCLUDED (NO FLOW. ENGINE VALVES CLOSED PRIOR TO DISCONNECT)

θ = VALVE CLOSING ANGLE
α = ANGULAR ACCEL.
t = VALVE CLOSING TIME = .071

$\therefore \theta = \frac{1}{2}\alpha t^2 \quad \therefore \frac{\pi}{4} = \frac{\alpha \times .00504}{2}$

$\alpha = \frac{2 \times .785}{.00504} = 311$ RAD/SEC^2



$\text{INERTIA} = \frac{W}{g}\left[\frac{\ell^2}{3} + \frac{R^2}{4}\right] = \frac{20}{32.2}\left[\frac{(.125)^2}{3} + \frac{(.453)^2}{4}\right] = .0348$ SLUG FT^2

$T = F_R \times \frac{1}{12} = I\alpha = .0348 \times 311 = 10.82$ FT#

$F_R = 130^{\#} \leftarrow$ DUE TO INERTIA

ASSUME ABOVE ROTATING MASS @ 20 LB = W

EQUIV. RPM $= S = \frac{\pi}{4} \times \frac{1}{.071} \times \frac{1}{2\pi} \times \frac{60}{1} = 105.5$

FOR A PADDLE TYPE IMPELLER,

$\text{EQUIV. H.P.} = \frac{Z S^3 L^4 W G N K V}{33000}$

WHERE Z = CONST. $= 0.6710 \times 10^{-7}$ ← DERIVED FROM TESTS
L = BLADE LENGTH = 5.45"
W = PROJECTED BLADE HT = 8.0"
G = SPECIFIC GRAVITY OF FLUID = 1.2
N = NUMBER OF BLADES = 2
K = MECH. EFF. = 1.2
V = VISCOSITY FACTOR = 1.0

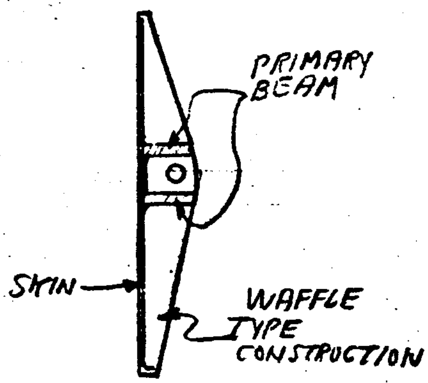
$\therefore \text{EQUIV. H.P.} = \frac{.671 \times 10^{-7} \times (105.5)^3 \times (5.45)^4 \times 8 \times 1.2 \times 2 \times 1.2}{33000}$

$= \frac{.671 \times .1175 \times 883 \times 23}{33} = .0486$

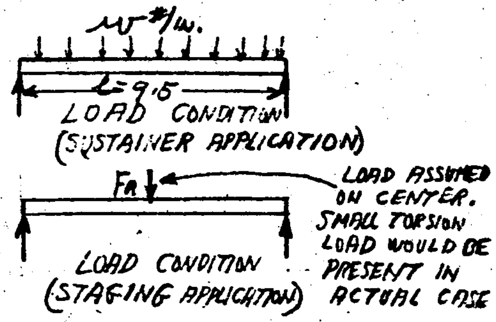
$\text{TORQUE} = \frac{5252 \times .0486}{105.5} = 2.42$ FT# = 29.0"#

$\therefore F_R = 29.0^{\#}$ USING 1" ARM. TOTAL $F_R = 159^{\#} \leftarrow$ DUE TO INERTIA AND PADDLE EFFECT.

BASIC BUTTERFLY STRUCTURE ESTIMATE

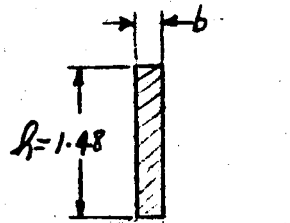


$W = l \times w$



$$\underset{\text{(SUSTAINER APPLICATION)}}{M} = \frac{Wl}{8} = \frac{10,900 \times \overset{\text{LOAD FACTOR}}{1.5} \times 9.5}{8} = 19,400''\#$$

$$\underset{\text{(STAGING APPLICATION)}}{M} = \frac{Wl}{4} = \frac{9000 \times 1.5 \times 9.5}{4} = 32,100\ ''\#$$



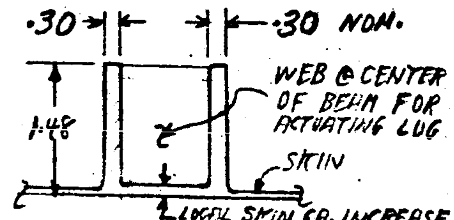
(EQUIV. SECTION)

$$I = \frac{bh^3}{12} = \frac{b \times (1.48)^3}{12} = .270\ b$$

$$*S = \frac{Mc}{I} = 150,000 = \frac{32,100 \times .74}{.270\ b}$$

$$\therefore b = \frac{23,800}{40,500} = .588$$

SEE SHT #5 of 5 FOR OTHER INFLUENCING FACTORS



APPROX. DESIGN

ENDS OF BEAM SOLID MATL FOR RECEIVING PINS

BEAM @ CENTER OF SPAN COULD BE BOX TYPE SECTION FOR TRASMITTING TORSION EFFECTIVELY.

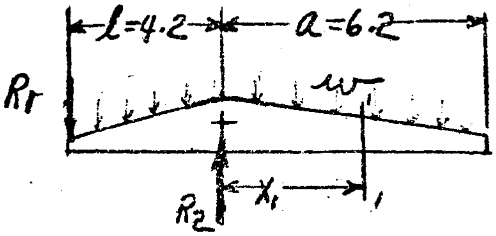
* THE GUARANTEED VALUES OF 718 INCONEL

ROOM TEMP. → $F_{TY} = 150,000$; $F_{TU} = 180,000$

100,000; 125,000 } K MONEL VALUES. GUARANTEED ROOM TEMP. VALUES.

BASIC BUTTERFLY STRUCTURE ESTIMATE (CON'T.)

SHT. #2 OF 5



LOAD CONDITION

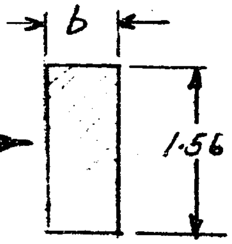
FOR SIMPLIFICATION, ASSUME UNIFORM LOAD

w = LOAD #/INCH

$= \frac{10930 \times 1.5}{10.4} = 1{,}572$ (1.5 = LOAD FACTOR)

BEAM DEPTH @ R_2 = 1.56"

EQUIVALENT CROSS SECTION →

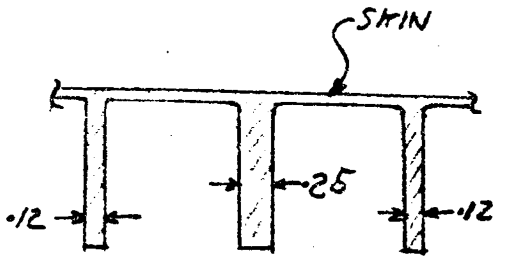


MOMENT OF INERTIA $I = \frac{b \times (1.56)^3}{12} = .316\,b$

BENDING MOMENT AT R_2 $= M_{R_2} = \frac{w a^2}{2} = \frac{1572 \times (6.2)^2}{2} = 30{,}200$ IN.#

$S_Y = 150{,}000 = \frac{Mc}{I} = \frac{30{,}200 \times .78}{.316\,b}$

$\therefore b = \frac{23{,}600}{47{,}400} = .498$



* DISTRIBUTE MAT'L INTO THREE PRIME RIBS

BEAM DEPTH @ X_1 → .87"

BENDING MOMENT AT $X_1 = 3.5$ $= \frac{w}{2}(a - x_1)^2 = \frac{1572 \times (2.7)^2}{2} = 5{,}730$ in#

$I_{@ x_1 = 3.5} = \frac{b \times (.87)^3}{12} = .0548\,b$

$b_{@ x_1} = \frac{5730 \times .435}{.0548 \times 150{,}000} = .303$

* SECTION MAY ALSO BE INFLUENCE BY THE FINAL SEAL DESIGN WHICH MAY OR MAY NOT BE SENSITIVE TO CLOSURE DEFLECTIONS.

BASIC BUTTERFLY STRUCTURE ESTIMATE (CONT)
(SKIN CHECK)

SHT. 3 OF 5

IN DETAIL ANALYSIS, TRADE OFFS WILL BE REQUIRED BETWEEN NUMBER OF WEBS AND SKIN THICKNESS. THE SKIN WILL ALSO BE SUBJECT TO LOADS OTHER THAN PRESSURE. FABRICATION SHOULD ALSO BE CONSIDERED. FOR ESTIMATING, A THICKNESS (t) OF .060 IS USED.

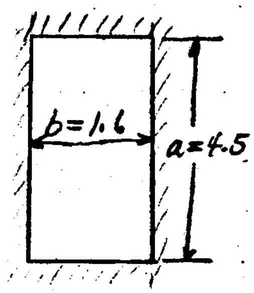
USING AN AREA SHOWN BELOW WITH ALL EDGES FIXED, THE FOLLOWING RELATIONS ARE USED.

$\alpha = \frac{b}{a} = \frac{1.6}{4.5} = .356$

$\alpha^6 = .00204$

$b^2 = 2.56$

$W = 178$ psi $\qquad t^2 = .0036$

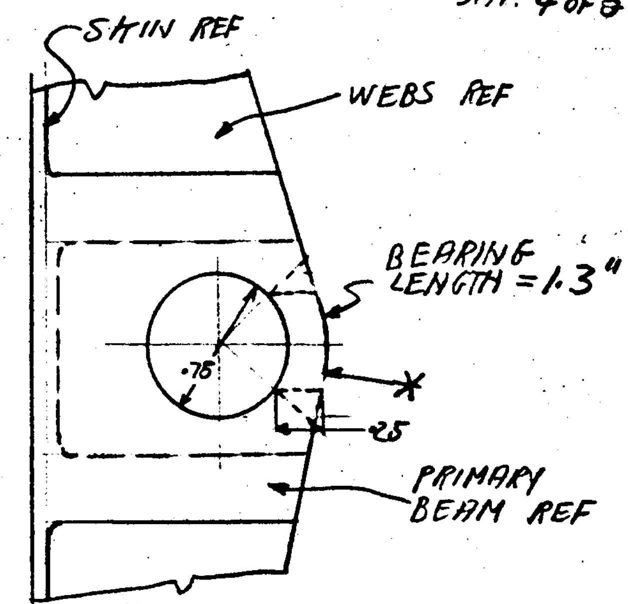


$$S_{\text{MAX @ CENTER OF LONG EDGES}} = \frac{.5 W b^2}{t^2(1 + .623\alpha^6)} = \frac{.5 \times 178 \times 2.56}{.0036 \times 1.0013} = \frac{228.0}{.0036} = 63{,}300 \text{ psi}$$

THE TRANSMISSION OF LOADS FROM THE PRIMARY BEAM TO THE CANTILEVER WEBS COULD CAUSE SKIN BUCKLING. WHICH IN TURN DEPENDS UPON THE DETAIL WAFFLE DESIGN. THE .060 FIGURE APPEARS REASONABLE.

BASIC BUTTERFLY STRUCTURE ESTIMATE

SHT. 4 OF 5



* LOCAL SECTION INCREASE MAY BE REQ'D DUE TO HEEL OR TOE ACTIONS BETWEEN PIN + BORE CAUSED BY DEFLECTIONS.

LOAD FROM SUSTAINER APPLICATION; LOAD FACTOR

$$\text{MAX LOAD PER PIN} = \frac{10{,}900 \times 1.5}{2} = 8{,}175^{\#}$$

$$\text{AVG. BEARING STRESS} = \frac{8175}{.75 \times 1.3} = 8390 \text{ psi}$$

SEE PAGE 108(a) FOR ADDITIONAL DETAILS.

$$\text{TEAR OUT STRESS} = \frac{8175}{.25 \times 1.3 \times 2} = \frac{8175}{.65} = 12{,}570 \text{ psi}$$

$$\text{PIN SHEAR} = \frac{8175}{.442} = 18{,}500 \text{ psi}$$

MAINTAIN LOW BEARING STRESS & MAKE PINS HOLLOW IF WT. DICTATES.

(BENDING CHECK:)

REFERRING TO SHT. 5 OF 5, DEFLECTION OF THE PRIMARY BEAM COULD CAUSE A LOAD CONDITION ON THE PINS PER FIG. A. THEREFORE THE BENDING CONDITION RESULTING FROM THIS DEPENDS UPON THE CLEARANCES BETWEEN PIN, HOUSING + BUTTERFLY AND DEFLECTION OF THE PIN ITSELF.

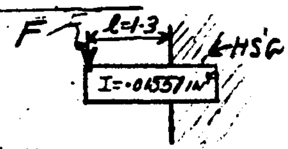


FIG. A

∴ PERMISSABLE

$$F \text{ @ CONDITION PER FIG. A} = \frac{150{,}000 \times .01551}{1.3 \times .375} = 4{,}770^{\#}$$

$$\text{PIN DEFLEC. @ } F = 4770 = \frac{4770 \times 2.2}{90 \times .0155 \text{ in}^4} = .00750''$$

SUFFICIENT TO EASILY COMPENSATE FOR BEAM END ROTATION.

HEEL & TOE ACTION ESTIMATE OF BUTTERFLY PINS

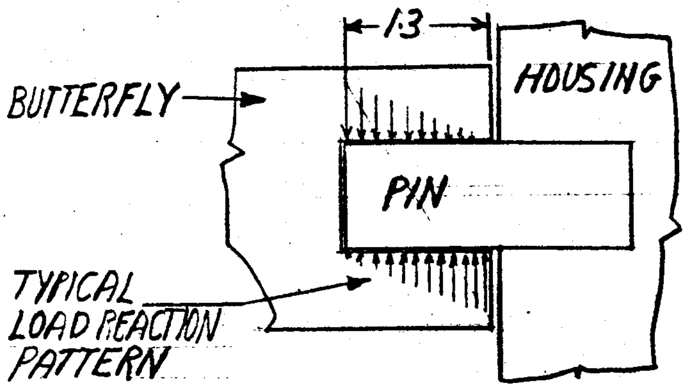


FIGURE "A"

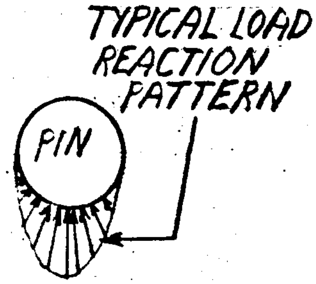


FIGURE "B"
(END VIEW)

THE LOAD DISTRIBUTIONS SHOWN IN FIGURES "A" & "B" ARE INFLUENCED BY THE BUTTERFLY BLADE DEFLECTIONS; PIN DEFLECTION AND CLEARANCES BETWEEN PIN, BUTTERFLY & HOUSING. FROM THE CONVAIR DESIGN MANUAL, SECTION 7, PAGE 7-2-11 THE RELATIONS FOR AN ECCENTRIC LOADED BOLT IS:

$$F_{br} = \frac{P}{tD} + \frac{6P(e + t/2)}{Dt^2}$$ = MAX. BEARING STRESS @ POINT "A" (SEE FIG. "C")

FOR A CONSERVATIVE APPLICATION TO THE CASE PER FIG. "A", LOAD "P" (RESULTANT OF THE FORCE SYSTEM) IS ASSUMED @ $1.3/2 = .65 =$ "e". THIS LOAD LOCATION IS CONSIDERED REASONABLE IN ABSENCE OF DETAIL DESIGN DATA WHICH IS BEYOND THE SCOPE OF THIS REPORT.

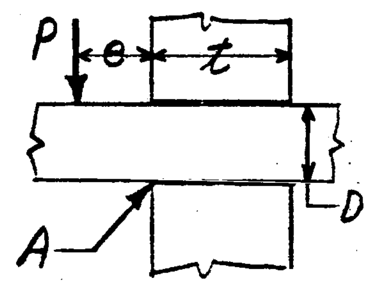


FIGURE "C"

THE MAX. BEARING STRESS @ PT. "A" IS THEN PER THE FOLLOWING:

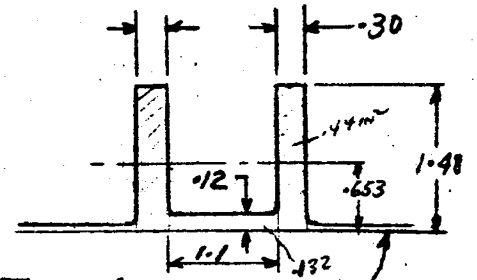
$$F_{br} = \frac{8175}{1.3(.75)} + \frac{6(8175)(.65 + 1.3/2)}{.75(1.3)^2} = 8380 + 50{,}300 = 58{,}680 \text{ PSI.}$$

USING: $P = 8175$
$t = 1.3$
$D = .75$
$e = .65$

BUTTERFLY STRUCTURE ESTIMATE

$F_R = 8200 \times 1.5 = 12300^{\#}$

FILL + DRAIN APPLICATION

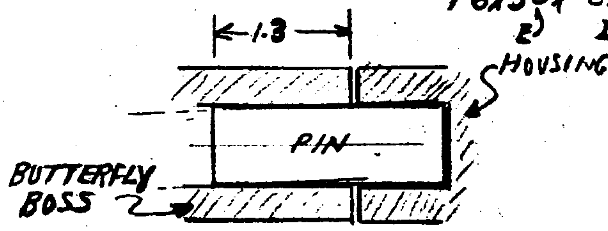


$I = .216 \text{ in}^4$ FOR SECTION SHOWN

$$\text{DEFLECTION} = \frac{F_R \ell^3}{48 E I} = \frac{12{,}300 \times (9.5)^3}{48 \times 30 \times 10^6 \times .216}$$

$$= \frac{10.52}{311} = .0338'' \, *$$

$$\text{SLOPE @ FREE ENDS} = \frac{\overset{F_R}{12{,}300} \times (\overset{\ell}{9.5})^2}{16 \times \underset{E}{30} \times \underset{I}{.216} \times 10^6} = \frac{1.081}{103.8} = .01070 \text{ RAD.} \, *$$



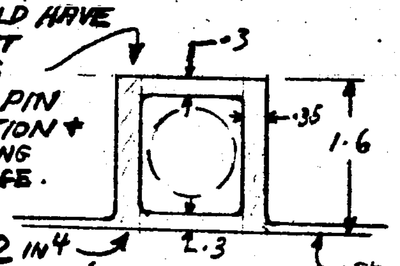
SECTION AT PIN

* THESE DEFLECTIONS COULD CAUSE BINDING @ PINS FOR THE FILL + DRAIN APPLICATION. THE ABOVE BEAM SECTION SHOULD THEREFORE IN DTL DESIGN REFLECT A CAP SECTION AS SHOWN BELOW. DEPTH COULD ALSO BE INCREASED SLIGHTLY WITH SAME ACTUATION STROKE.

$$\text{MAX DEFL. FOR ALT. SECTION} = \frac{12300 \times (9.5)^3}{48 \times 30 \times 10^6 \times .522} = .01405$$

$$\text{END SLOPE} = \frac{12300 \times (9.5)^2}{16 \times 30 \times .522 \times 10^6} = .00444 \text{ RAD.}$$

BEAM WOULD HAVE LOCAL SLOT NEAR BOSS AREA FOR PIN INSTALLATION + FOR PREVENTING BLIND PASSAGE.



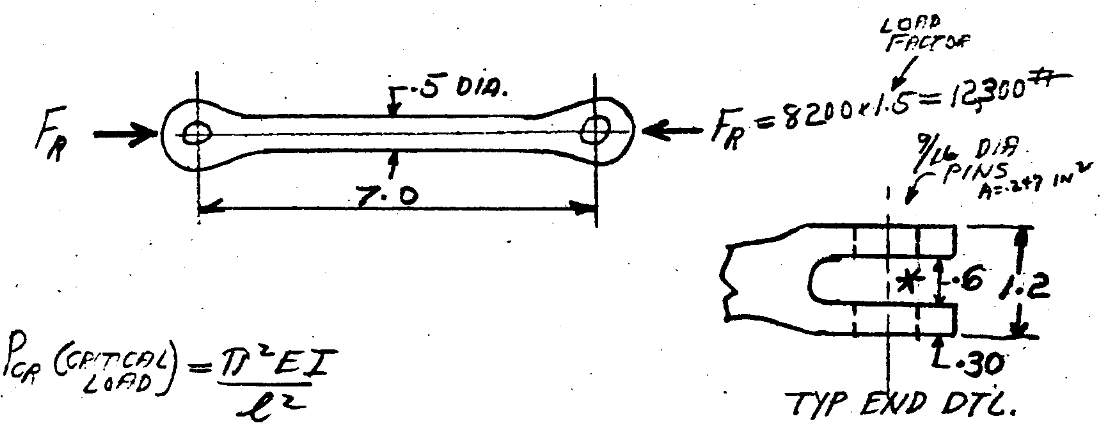
$I = .522 \text{ in}^4$

ALT. DESIGN.

CONSERVATIVE SECTION. THE BEAM IN DTL DESIGN COULD BE BORED OUT AS SHOWN @ DOTTED LINES WHEN MACHINING FOR THE SUPPORT PINS.

THE BUTTERFLY DEPTH SHOWN ON FIG. 1-4 APPEARS REASONABLE.

ACTUATOR ROD CALC.



$$P_{CR}\ (\text{CRITICAL LOAD}) = \frac{\pi^2 E I}{\ell^2}$$

$$I = \frac{\pi \times (.5)^4}{64} = .00307$$

$$P_{CR} = \frac{9.85 \times 3070 \times 30}{49} = 18{,}500\#$$

F_R AT STAGING CONDITION

$$S_{BR} = \frac{9000 \times 1.5}{.562 \times .6} = \frac{13{,}500}{.337} = 40{,}000 \text{ PSI.}$$

$$\underset{PIN}{S_s} = \frac{13{,}500}{2 \times .247} = 27{,}300 \text{ PSI.}$$

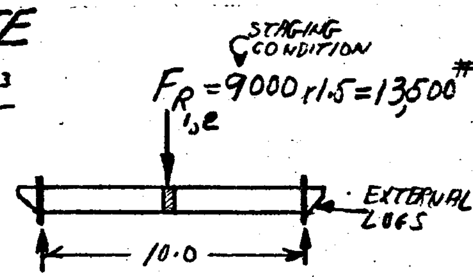
$$\underset{TEAR\ OUT}{S_s} = \frac{13{,}500}{4 \times .25 \times .30} = 45{,}000 \text{ PSI.}$$

DUE TO THE TENSION CONDITION @ STAGING.

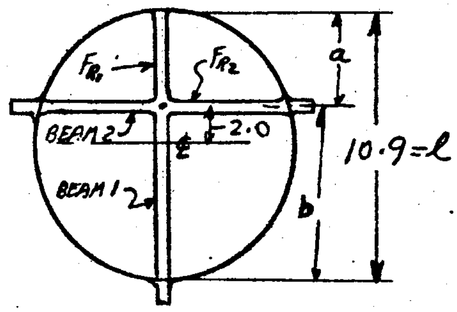
* MATING LUGS ON BUTTERFLY BEAM & CROSS BEAM IN THE FLEX DUCT SECTION WOULD HAVE LOCAL GAGE INCREASE FOR MAINTAINING BEARING STRESSES EQUAL TO OR LOWER THAN THE VALUE SHOWN.

SUPPORT WEB ESTIMATE

DEFLECTION AT POINT OF LOAD FOR BEAM 1 $\Big\} = \dfrac{F_{R_1} a^2 b^2}{3EI\ell}$ DEFLECTION @ LOAD FOR BEAM 2 $\Big\} = \dfrac{F_{R_2} \times \ell^3}{48EI}$



CHECK LOAD DISTRIBUTION;



EQUATING DEFLECTIONS $\dfrac{F_{R_1}(3.45)^2 \times (7.45)^2}{3 \times 30 \times I_1 \times 10.9 \times 10^6} = \dfrac{F_{R_2} \times (10)^3}{48 \times 30 \times 10^6 I_2}$

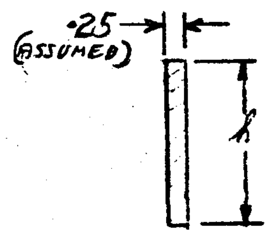
ASSUMING $I_1 = I_2$

$$.673 F_{R_1} = .695 F_{R_2}$$

AND $F_{R_1} + F_{R_2} = 13{,}500$

$$1.368 F_{R_1} = 9380$$

$$\therefore F_{R_1} = 6870^{\#}$$
$$F_{R_2} = 6630^{\#}$$



$$M_{\text{DUE TO } F_{R_1}} = \frac{6870 \times 3.45 \times 7.45}{10.9} = 16{,}150 \text{ in}^{\#}$$

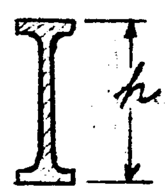
$$M_{\text{DUE TO } F_{R_2}} = \frac{6630 \times 10}{4} = 16{,}580 \text{ in}^{\#}$$

$$S = \frac{16{,}580 \quad .5 \times h}{\frac{.25}{12} h^3} = \frac{8290}{.0208 h^2} = \frac{398{,}000}{h^2}$$

USING 718 INCONEL, $h^2 = \dfrac{389{,}000}{150{,}000} = 2.66$ $\quad h = 1.63$

$$S_{S \text{ IN WEB}} = \frac{3}{2} \times \frac{3435}{.25 \times 1.58} = \frac{10{,}300}{.79} = 13{,}050 \text{ PSI.}$$

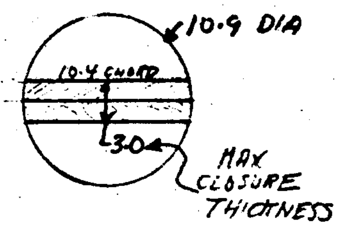
CAN DISTRIBUTE MATL AS SHOWN FOR INCREASED LATERAL STABILITY. LIMIT OF WEB GAGE REDUCTION HOWEVER MAY BE CONTROLLED BY BUCKLING.



ΔP ESTIMATE

NET FLOW AREA = 93.2 − 10.9 × 3 = 60.5 IN² = .420 FT²   EQUIV. DIA. = 8.77"

FLOW RATE = 710 FT³/MIN. = 11.85 FT³/SEC



$$VEL = \frac{11.85}{.42} = 28.2 \text{ FT/SEC}$$

VISCOSITY = .30 CENTIPOISES @ −320

$$N_{REY\#} = \frac{6.32 \times 710 \times 94 \times 60}{8.77 \times .3} = 9.6 \times 10^6$$

$$f = .028$$

WETTED PERIMETER $= \pi \times 10.9 + 2 \times 10.4 - 6 = 49.0$

$$R_H = \frac{AREA}{WETTED\ PERIMETER} = \frac{60.5}{49.0} = 1.235$$

$$\Delta P = f\left[\frac{L}{R_H}\right]\rho\frac{V^2}{2g}$$ WHERE $\rho = 94\ \#/FT^3$

$$\frac{V^2}{2g} = \frac{(28.2)^2}{64.4} = 12.35$$

L = LENGTH OF FLOW PASSAGE.
USE LENGTH OF BLADES = 14.5" = 1.21'

$$\therefore \Delta P = .028\left[\frac{1.21}{1.235}\right]94 \times 12.35 = 31.8\ \#/FT^2$$

$$= .222 \text{ PSI.}$$

ASSUMING FLOW PASSAGE BLOCKED OFF AS SHOWN,
LOSS FOR SUDDEN CONTRACTION

EQUIV DIA. = 8.77
APPROACH DIA. = 10.9 $\therefore \frac{8.77}{10.9} = .804$

RESIS. COEF $\therefore = .13 = K$

$$\therefore \Delta P = .13 \times 94 \times \frac{(18.3)^2}{64.4} = 63.6\ \#/ft^2 = .442 \text{ PSI.}$$

FOR SUDDEN EXPANSION

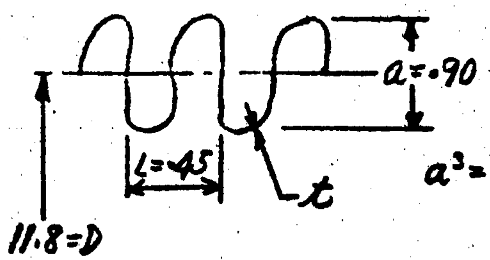
$$\therefore K = .13$$

$$\Delta P = .13 \times 94 \times \frac{(28.2)^2}{64.4} = .13 \times 94 \times 12.35 = 151\ \#/ft^2 = 1.048 \text{ psi}$$

TOTAL $\Delta P = .22 + .44 + 1.05 + \underset{\text{FOR BELLOWS}}{.76} = \underline{2.47}$ PSI.

BELLOWS ESTIMATE

SHT. 1 OF 2



$a^3 = .728$

$t^2 = .000625$

USING $t = .025$

$\frac{t}{a} = \frac{.025}{.90} = .0278$

$\left(\frac{t}{a}\right)^3 = .0000215$

SPRING RATE PER CONVOLUTE $= F = 1.2\,ED\left[\frac{t}{a}\right]^3 = 1.2 \times 30 \times 11.8 \times 21.5 = 9130\ \#/\text{IN.}$

ALLOW PRESS. $P_M = \frac{3.5 \times 10^5 t^2}{a(1.5a + t)} = \frac{3.7 \times 62.5}{.9 \times 1.375} = 187.0$ PSIG

ALLOW. DEFLECTION PER CONVOLUTE $= \Delta_M = \frac{.0111\, a^3}{t^2\left(\frac{3a}{t}+1\right)} = \frac{.0081}{.0681} = .119$ INCHES

SPRING RATE FOR 11 CONV SECTION. $= \frac{F}{N} = \frac{9130}{11} = 830\ \#/\text{IN DEFL.}$

FOR EQUAL SPRING RATE IN 17 CONV. SECTION,

$$\frac{1.2 \times 30 \times 10^6 \times 11.8 \times \frac{t^3}{.728}}{17} = 830 \quad \therefore t = \left[.0000241\right]^{1/3} = .029$$

Δ_M FOR .029 ga. $= \frac{.0081}{.079} = \pm .1026$ IN.

TOTAL Δ FOR 17 CONV. SECTION $= \pm 1.745$ *

* CAN EXCEED THIS VALUE WITH USE OF 718 INCONEL OR K MONEL

BELLOWS ESTIMATE

SHT #2 OF 2

* TOTAL Δ FOR 11 CONV. SECTION $= \pm 1.31$

ΔP CHECK

MAX FLOW $= 5320$ G.P.M. $= 710\ FT^3/M = 11.81\ FT^3/SEC$

FLOW AREA $= \frac{93.2}{144} = .647\ FT^2$

$V_{EL} = \frac{11.81}{.647} = 18.28\ FT/SEC$

FRICTION FACTOR $f = \frac{.4 \times 10.9}{.45}\left[\frac{.9}{10.9}\right]^{1.6} = .188$

$$\Delta P = \frac{f\, g\, V^2}{288\, G\, D_i} = \frac{.188 \times 94 \times (18.28)^2}{288 \times 32.2 \times 10.9} = \frac{5900}{101000}$$

$= .0584$ PSI/IN.

TOTAL $\Delta P = .0584 \times 13 = .758$ PSI.

SQUIRM CHECK Δ_ℓ = ACTUAL DEFLEC/CONV. (USE .12)

$$\frac{LN^2(\pi D^2 P + 4F\Delta\ell)}{19.7 F D^2} = \frac{82,380 \times 353}{251 \times 10^5} = 1.16$$

COL. UNSTABLE SINCE THIS IS >1

$$P_{CR} = \frac{6.28 F}{LN^2} = \frac{6.28 \times 9130}{.45 \times (28)^2} = 162.6 \text{ PSIG}$$

$$\Delta_{CR} = \frac{\pi^2 D^2}{2LN^2} = \frac{\pi^2 \times (11.8)^2}{2 \times .45 \times (28)^2} = \frac{1375}{705} = 1.95 \text{ INCHES}$$

SQUIRM SHIELD IS REQ'D.

DISCONNECT BAND ESTIMATE

FRICTION NEGLECTED SHT #1 OF 2

$\alpha = 20°$

$TAN\,\alpha = .36$

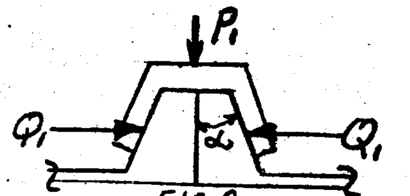


FIG. A

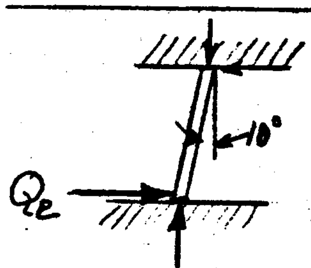
LOAD DUE TO PRESSURE
(VENT APPLICATION)

$P_1, P_2 \,\&\, P_3$ REFER TO RADIAL LOAD ON BAND.

$Q_1, Q_2 \,\&\, Q_3$ REFER TO AXIAL LOAD ON BAND.

$$Q_1 = \frac{\overset{\text{PRESS.}}{35} \times \overbrace{.785 \times (11)^2}^{\text{AREA}}}{\underbrace{\pi \times 11}_{\text{CIRCUMFERENCE}}} = \frac{3330}{34.5} = 96.5\ \#/\text{IN.}$$

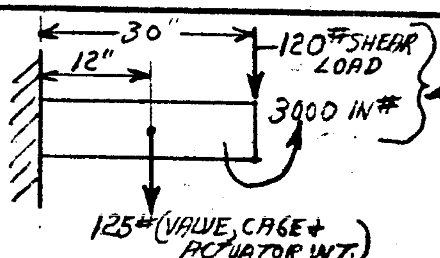
$$P_1 = 2Q_1 \tan\alpha = 2 \times 96.5 \times .36 = 69.5\ \#/\text{IN.}$$



$$Q_2 = 500 \times \sin 10° = 500 \times .173 = 86.5\ \#/\text{IN}$$

$$P_2 = 2Q_2 \tan\alpha = 2 \times 86.5 \times .36 = 62.2\ \#/\text{IN}$$

LOAD DUE TO SEAL



LOADS DUE TO VENT APPLICATION

I = MOMENT OF INERTIA @ FLG NECK (SEE FIG A)

$$I = \left[(11.04)^4 - (10.9)^4\right] \times \frac{\pi}{64} = 383\ \text{IN}^4$$

TOTAL MOMENT $M = 120 \times 30 + 125 \times 12 + 3000 = 8100$ IN #

$$S = \frac{Mc}{I} = \frac{8100 \times 5.52}{383} = 116.6\ \text{PSI.}$$

$$\therefore Q_3 = \underset{\text{FLG. NECK THICKNESS}}{.07} \times 116.6 = 8.16\ \#$$

$$P_3 = 2 \times 8.16 \times .36 = 5.9\ \#/\text{in}$$

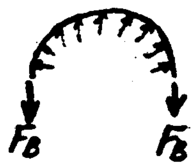
DISCONNECT BAND ESTIMATE (CONT.)

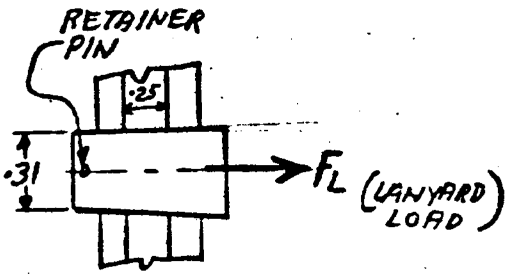
SHT #2 OF 2

$$P_1 + P_2 + P_3 = 69.5 + 62.2 + 5.9 = 137.6 \ \#/IN$$

$$F_B = \frac{137.6 \times 12''}{2} = 825\#$$

DIA.





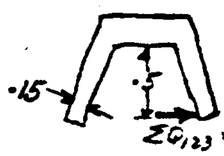
RELEASE PIN (SCHEMATIC)

ALLOWING 100# TO SHEAR RETAINER PIN,

$$F_L = 825 \times 1.5 \times .20 + 100 = 348\#$$

LOAD FACTOR; FRICTION COEFF. μ

$$\text{BEARING STRESS} = \frac{825 \times 1.5}{.3 \times .25} = 16{,}500 \ PSI.$$



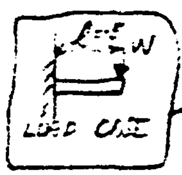
BAND CROSS SECTION

$$\text{BENDING MOMENT} = 191.6 \times 1.5 \times .5 = 143.5 \ IN\#$$

$(Q_1+Q_2+P_3)$; LOAD FACTOR; ℓ_{ARM}

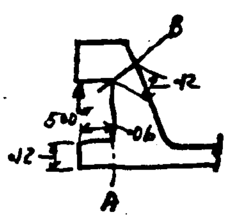
$$I = \frac{bh^3}{12} = \frac{1 \times (.15)^3}{12} = .000281 \ IN^4$$

$$S = \frac{Mc}{I} = \frac{143.5 \times .075}{.000281} = 38{,}300 \ PSI.$$



$$\text{DEFLECTION} = \frac{143.5 \times (.5)^3}{90 \times 281} = .000708''$$

$$\frac{W\ell^3}{3EI}$$



$$\text{SHEAR STRESS THRU PLANE } A = \frac{500}{.12} = 4170 \ PSI.$$

$$I_{AT\ PLANE\ 'B'} = \frac{bh^3}{12} = \frac{1 \times (.12)^3}{12} = .000144$$

$$\text{BENDING MOMENT @ 'B'} = 500 \times .06 = 30 \ IN\#$$

$$\text{BENDING STRESS @ 'B'} = \frac{30 \times .06}{.000144} = 12{,}500 \ PSI. = S_B$$

USING A NOTCH FACTOR OF 4; $S_B \cong 50{,}000$ PSI.

WEIGHT BREAKDOWN

BUTTERFLY (INCL. PINS + SEAL) ———— 8.67# EA.

VALVE HOUSING ———— 6.75# EA.

FLEX SECTION ———— 25.3#

SUSTAINER FITTING ———— 6.25#

ACTUATOR ROD ———— .5#

* ACCESSORIES ———— 7.0#

▲ TOTAL ASSEMBLY WT. ———— 69.89#

▲ AL. ALY. SUSTAINER FTG. REMAINING PARTS INCONEL OR K MONEL (INCLUDING ACCESSORIES)

* EXTERNAL "V" BAND, RELEASE PINS, CABLES, SQUIRM SHIELD, ETC.

GENERAL DYNAMICS

Convair Division